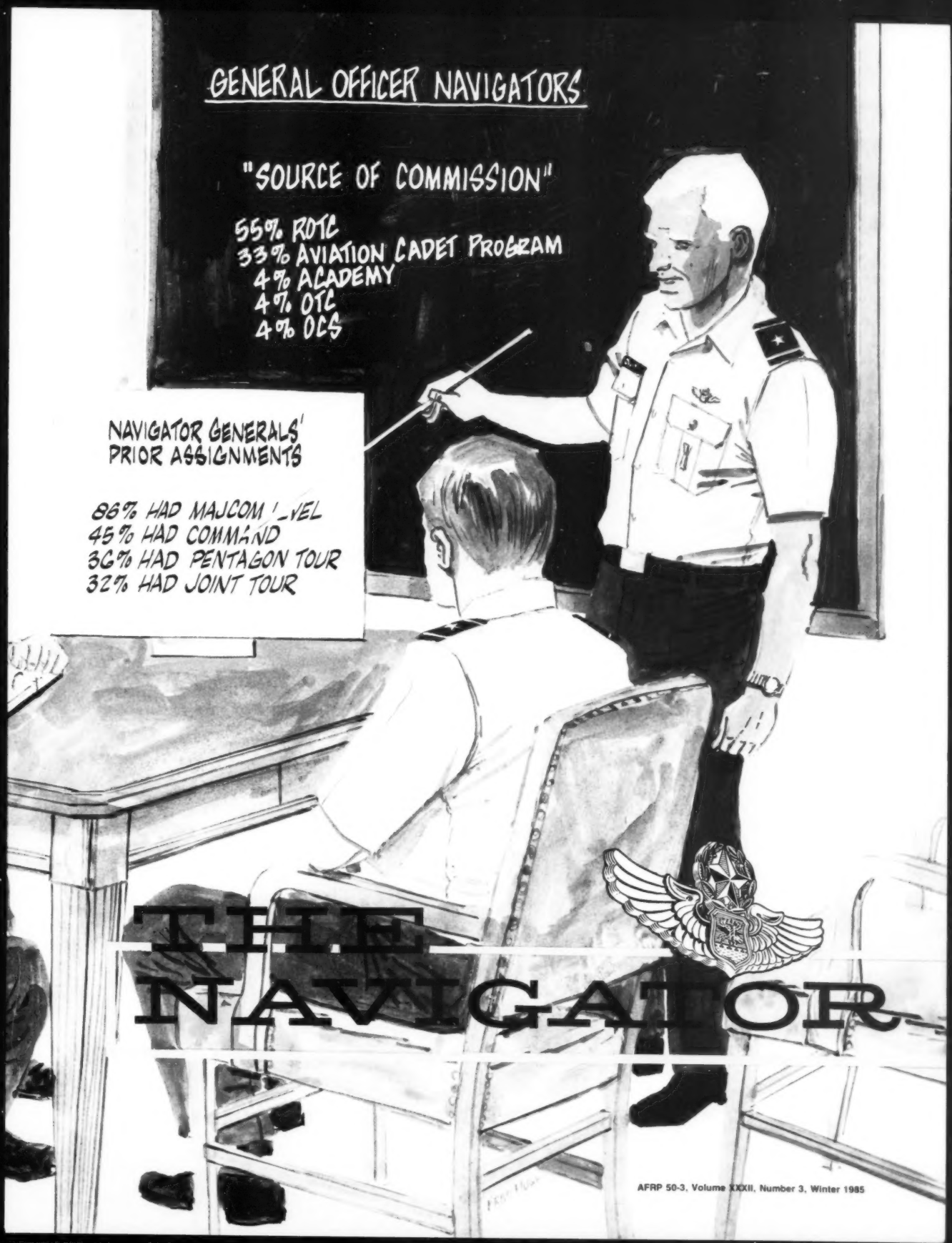

THE NAVIGATOR

AFRP 50-3, Volume XXXII, Number 3, Winter 1985

NAV OF NOTE

BRIGADIER GENERAL RICHARD L. STONER

One of the greatest challenges facing the Air Force today is acquiring reliable and affordable weapon systems. The ability to support those systems with available and affordable spare parts is equally vital to our national security. Our Nav of Note is a central figure in solving these dilemmas. Brigadier General Richard L. Stoner is the Director of Maintenance, Office of the Deputy Chief of Staf. for Logistics and Engineering, Headquarters U.S. Air Force, Washington, D.C.

Commissioned through the aviation cadet program at Harlingen AFB, Texas, General Stoner received his navigator rating in 1957. His first duty assignment was with the 1st Air Transport Squadron, Dover AFB, Delaware as a line navigator flying C-124s and C-133s. "It was a challenging yet fun assignment. We did most of our flying to Europe, at 8,000 feet, with a sextant, APN-70 LORAN and drift meter for precision navigation. Experience came fast, as I flew about 100 hours per month during my five years in the squadron."

In 1962, Gen Stoner was assigned to AFIT at Wright-Patterson AFB, Ohio where he obtained an undergraduate degree in engineering. "At that time, the Air Force was moving toward an officer corps possessing college degrees. AFIT allowed me to study a subject I found interesting; electronics, and its applications to navigation." Following AFIT, he remained at Wright-Patterson at what is now the 4950th Test Wing as a flight test engineer. The general was involved in testing inertial navigation systems, the electrostatically suspended gyro, and satellite communications systems.

He returned to operational flying in 1969 as a navigator and fire control officer on AC-119G gunships, at Tan Son Nhut Air Base, Republic of Vietnam. "The mission was night application of firepower, usually within 100 meters of the friendlies. Since we didn't have any sophisticated navigation equipment, it was basic DR and map reading to get the job done." The general flew 160 combat missions while a member of the 17th Special Operations Squadron. Returning from Vietnam, Gen Stoner served as a flight test engineer on airborne weather radars at Scott AFB, Illinois.

After completing a master's program in engineering at New Mexico State University in 1972, Gen Stoner entered the logistics world at Ogden Air Logistics Center (ALC), Hill AFB, Utah. "Command billets for navigators were very limited in the early seventies. Some great challenges for the future of the Air Force lay in the logistics, and research and development areas. My experiences as a navigator, supplemented by education and duty in engineering, helped open the door. However, I realized that whether it's planning a course to reach the destination, throwing out a DR, or finding and correcting the deficiencies of a new system, the same logical methods are involved. You must plan a course to reach the objective." While at Hill, he was Chief of the Missile Engineering Section and Commander of the 2952d Combat Logistics Support Squadron. "My navigator background paid off again, as Ogden was responsible for all ICBMs, and our biggest task was solving guidance problems on these missiles."

In 1977, the general was Director of Engineering Services at the newly-formed Air Force Acquisition Logistics Division at Wright-Patterson AFB. "ALD allowed us the means to apply lessons learned to new systems being procured by the Air Force." After attending Air War College, Gen Stoner returned to the Ogden ALC as Chief of the Service Engineering Division and the Resources Management Division in the Directorate of Maintenance.

Gen Stoner became the Director of Maintenance at the Oklahoma City ALC, Tinker AFB, Oklahoma in 1981. He was responsible for executive management of the Air Force's largest depot maintenance complex. "Even though I was removed more from the navigation business, that foundation as a nav still paid big dividends. This job was the most rewarding and challenging due to its magnitude. Problems involved

budget modification schedules and handling personnel matters for civilian and military. But the key to success could be traced to discipline and problem solving, similar traits used to keep an accurate log."

In 1983, Gen Stoner moved to the Pentagon as the Deputy Director for Logistics Plans and Programs, Office of the DCS for Logistics and Engineering. He was promoted to brigadier general and assumed his present position in June 1984.

Regarding advice for present and future navigators, the general said, "Don't avoid the hard jobs or unpleasant assignments. Look for jobs where others have failed. Then do that job well by knowing your position, being involved in your unit, and learning about the other persons involved—in operations, maintenance and supply. Finally, look for opportunities to communicate! It's second only to leadership, and most essential on any task!

MEET YOUR NEW EDITOR

Captain André LeDoux is a 1979 graduate of the University of Oregon where he was commissioned through the Air Force ROTC program. After receiving his wings in 1980, Captain LeDoux attended electronic warfare training at the prestigious 453d Flying Training Squadron, Mather AFB, California. He became qualified in the B-52 and reported for duty at K.I. Sawyer AFB, Michigan. During his three years at Sawyer, Captain LeDoux was an electronic warfare instructor and a friend to all as a member of the wing standardization/evaluation branch. When he returned to Mather in 1984, he was assigned to the 453d FTS as an instructor in B-52 Penetration Systems and Air Defense Systems.

FROM THE EDITOR

Captain André LeDoux

Read on

This issue of THE NAVIGATOR has a little something for everybody. Our cover story is recommended reading for those interested in how navigators have earned the rank of a general officer. There are some startling statistics and some basically good advice from the "big boys"who have been there. We have informative articles which will improve your celestial prowess or keep you safer when close to the weather. There's one story that addresses flight attitude—that is your mental, not aircraft, orientation. Although this story is written from a fighter crew member's standpoint, this author's advice applies to all fliers. We even have an article about the marines. Contrary to popular belief, they contribute more to the navigation field than "Sir, may I take a fix, sir." The standard features continue to enlighten. Our Nav of Note has proven throughout his career that the knowledge gained as a navigator can be applied to any transitional field. He stresses that to be a navigator is to be a problem solver. Of course, I've only mentioned a few of the top-notch stories within these pages. So, read on....

Keep those cards and letters coming in

Once again I would like to thank the authors who donated time from their busy schedules to make THE NAVIGATOR one of the best publications in the U.S. armed forces. To locate good quality material is an unending process and we depend on you, the reader, for these outstanding works. If you have any connection with navigation, you have an experience to share. If you're an aircrew member, civilian, maintenance troop, instructor, evaluator, or you know of someone who has served in a navigation-related job, submit a story, an idea or a phone number. Furthermore, don't limit yourself to present-day navigation. Get that story Uncle Ray tells every year at Christmas time about Ploesti. Pick your commander's brain about Arc Light. If you're a shop manager whose project deals with artificial intelligence or shuttle military applications, drop us a line. Most of our readers belong to the crew force and they are always curious as to where the career field is heading. Contribute to THE NAVIGATOR magazine and help us educate, inform, and create the warrior needed to defend the free world.

AFRP 50-3, Volume XXXII, Number 3, Winter 1985

Department of the Air Force

THE NAVIGATOR

Proudly Serving Air Force Navigators Around the World Since 1953

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To attain the rank of general is not in the sights of all who wear the navigator wings. The individuals who put in the effort and earned the stars are from varying lifestyles, aircraft, and commands. If you are interested in how the navigators of the past made the grade, Brigadier General Wood's article, "Plotting the Stars," is a must.

AFRP 50-3

Distribution: One copy per four navigators.

PLOTTING the STARS—

the General Officer Navigator

Brigadier General C. Norman Wood
DACS/I
The Pentagon

I was pleased when the staff of THE NAVIGATOR magazine asked me to share some of my research and thoughts on general officer navigators in the Air Force. While I was a major attending Air Command and Staff College, I wrote a research paper titled, "Navigator Generals - How They Got There." Since that paper was written in 1974, I have updated the data to include statistics through the last general officer promotion board. Within the last year I have personally communicated with most of the 22 general officers who have been promoted over the last seven promotion boards and wear navigator wings. They provided me with some personal insight and advice that, along with other research, I would like to share with the navigator force. Let me caveat this article from the beginning by emphasizing that *it is not intended as a road map for success.* Nor am I trying to imply that success will result if a person does all the things I talk about.

Many young navigators in the field today have never seen a general, much less one wearing navigator wings. I hope at least some of this information will be useful to you now or in the future as counselors or in your own career development. I want to describe some of these things but also make it clear there is no magic answer.

As a way of introduction and to establish my credibility, here is a brief biography of my career. After commissioning through Officer Training School* in 1960, I graduated from Undergraduate Navigator Training in 1961 and Electronic Warfare Officer School in 1962. My first aircrew tour was as an electronic warfare officer in RB-47s, followed by duties as an instructor electronic warfare officer in RC-135s. During my tour I logged more than 1,000 combat hours in Southeast Asia.

After almost nine years in the crew force, my primary flying duties ended in 1969, when I was assigned to the 544th Aerospace Reconnaissance Technical Wing and later HQ SAC at Offutt AFB, NE. While there, I served as an intelligence watch officer in the Indications and Warning Center and as a Soviet offensive naval weapons analyst; and later as Chief, Current Intelligence Branch, for the Deputy Chief of Staff, Intelligence.

In 1972, I was off to Southeast Asia as an action officer in the Plans, Training, and Management Division, J-2, Headquarters Military Assistance Command, Saigon, Vietnam. Later, I served as Chief of the Defense Analysis Branch, J-2, and briefed air intelligence to the Military Assistance Command Vietnam, Commander; the United States Ambassador to Vietnam; the Vietnamese Air Force Commander; and the Vietnamese Joint General Staff.

Following my Southeast Asia tour I went to the Air Command and Staff College, and then to the Pentagon as an action officer in the Coordinated Action Plans Division, of the Doctrine, Concepts and Objectives Deputate. In 1975, I became the executive officer in the Office of the Air Force History, after which I attended the National War College.

In 1979, I returned to Offutt as the Deputy Commander for Operations, 544th Strategic Intelligence Wing and later served as the Wing Commander. I also served as the Assistant Deputy Chief of Staff for Intelligence at HQ SAC. In 1982, I was selected to be the Executive Director of the President's Foreign Intelligence Advisory Board, at the White House. In 1984, I became the Deputy Director for the National

**Editor's Note: Brig Gen Wood was the first OTS graduate to become a general officer.*

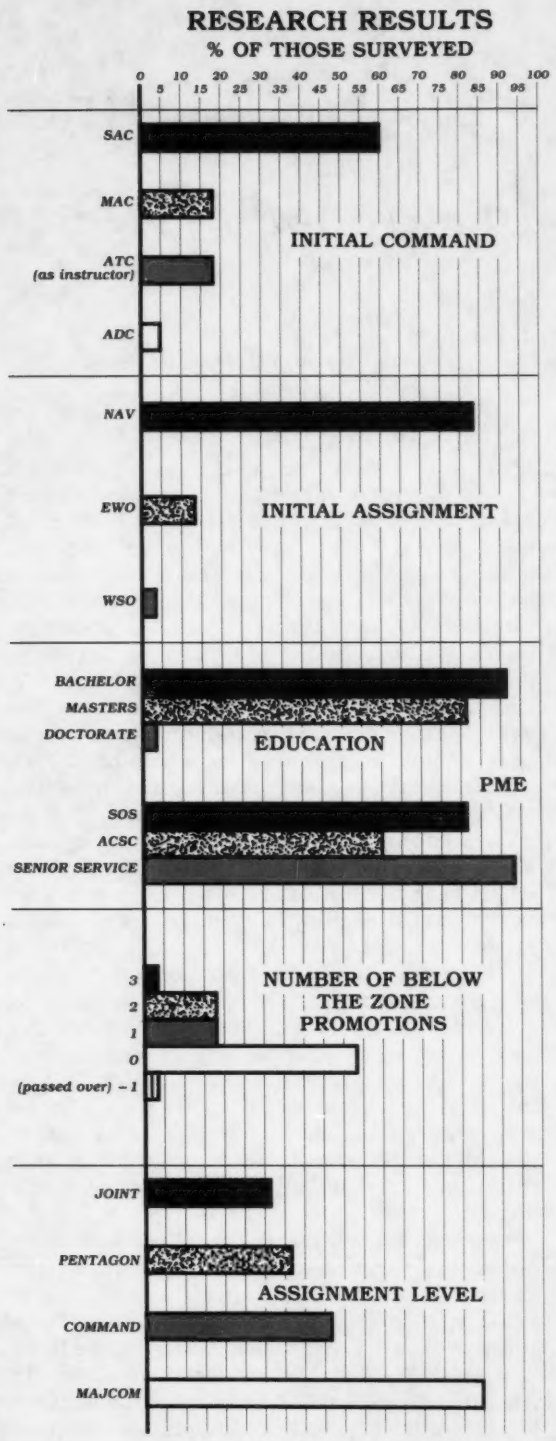
Strategic Target List, Joint Strategic Target Planning Staff at Offutt, and assumed my present duties as Assistant Deputy Chief of Staff for Intelligence at HQ USAF in May of this year.

Before really getting into the nuts and bolts of what navigator generals have done to make it to the top, let's briefly look at how the current AFR 36-23, Officer Career Development, describes an officer's career.

On the philosophy of advancement, AFR 36-23 states: "Each officer must recognize that career progression is a shared responsibility of the Air Force and the individual. Each officer who expects to perform in top senior grades must be aggressive in perfecting performance and in acquiring the diversified job experience, schooling and education as explained in this regulation." I cannot overemphasize that career progression is a shared responsibility. Remember it's your career and nobody has more to gain or lose than you. AFR 36-23 goes on to say, "Management of the rated officer resource is designed to identify career phase points over a full 30 year career." The young navigator should look through AFR 36-23 and compare his own career desires and phase points with those set forth by the formal personnel system. The personnel system can work; however, the system works to your advantage only through active participation.

All of these statistics are based on the 22 navigator generals who have been promoted over the last seven promotion boards. Some of the areas include: how many years spent in crew duty, assignments and job diversity, education, source of commission, and below-the-zone promotion information.

In the past, when talking with a group of navigators I always had the feeling that most were anxious to jump ship. They had that "I've got to get into a staff job as soon as I can" attitude. Well, statistically, up to this point, the navigator general officers have been in the crew force an average of eight years. Some were flying much longer than eight years and the minimum crew duty was four years. Of course, the younger officers in the field now are governed by the gate system, which really didn't effect those who are navigator generals now. Few will be able to leave the crew force permanently prior to having nine years flying time. The point I would make with young navigators is that you don't have to be in a hurry to get off a crew. There is still opportunity once you com-



plete your gate time. As I said earlier, I spent nine years in the crew force myself.

During my research, four assignment levels jumped out as being important things to do to increase your promotion potential. These include a MAJCOM level assignment, a joint assignment, a Pentagon tour, and having a command.

Of the navigators who have made general, 86 percent had a MAJCOM level assignment, 45 percent had a command, 36 percent had a Pentagon tour, and 32 percent had a joint tour. How does this translate? Each of these assignment levels increased their promotion potential, but they did not have to have them all. Only four percent had served in all four assignment levels. Nine percent served in three, while 60 percent had two, but all the generals had at least one of these assignment levels. The real surprise was that just *under half* had a command. Previously, I believed the command assignment was a "must" for promotion to general. The level of command did not appear to matter—some had squadrons, while others had wings. In my opinion, the command is a little more important than the other assignments and given the opportunity, that is what I would recommend. Successfully completing two out of four of these assignment levels, including a command, will certainly increase your competitiveness for promotion.

When I looked at the jobs the navigator generals held and how many moves they made, it became evident that you cannot stay in one place or one command and expect to reap the benefits of senior promotion. By statistical example, I considered crew time (8 years average) and the average time to make general (25 years) and came up with a number which is really the period of time they had to make a name for themselves and get promoted. This turned out to be 16 or 17 years. The average number of moves they made in those 17 years was 8.2. This was the most consistent fact in all of their backgrounds—*a move on the average of every two years.*

The importance of education and PME in the promotion equation has varied from promotion board to promotion board and at all rank levels. However, as long as the Air Force no longer has a controlled OER system, their significance will not decline.

Statistically, I found that of the navigator generals, 9 percent had no college degree, 9 percent had a bachelor's degree, 77 percent had a master's degree, and 5 percent had a doctorate. With more than 58 percent of the total officer force now having a master's degree, this fact will be reflected in future promotion statistics. Remember, when most of the current navigator generals entered the service, a degree was not required. As technology and competition continue to grow, the advanced degree will continue to increase in importance as a measure of your promotion potential.

It is hard to quantify the professional military education statistics for the careers of the navigator generals I studied. As indicated earlier, PME emphasis for promotion has changed over the years. Only 81 percent had SOS, 59 percent had completed intermediate service school but, most importantly, 95 percent had completed senior service school. I asked several of the generals, "Why didn't you get ACSC?" or "Why didn't you get SOS?" In many cases their answer was because promotions were going so fast. By the time they were eligible for school, they had been selected for early promotion to the next grade and became ineligible for the school. As many of you know, the eligibility requirements for PME schools also have changed several times over the years. Today, you must complete all three levels of PME to remain competitive for senior promotions.

When I looked at the "source of commission," I didn't find anything unusual. The statistics are added here for information and might have been more meaningful if compared to pilots and nonrated officer statistics. ROTC accounted for 55 percent of the navigator generals, while 33 percent came from the aviation cadet program and 4 percent each from an academy, OTS and OCS. Several more years of data and another look will be in order in the future.

Below-the-zone promotion statistics were one of the most interesting areas of my research for two reasons. First, the only way to find out whether a general had a below-the-zone promotion was by asking him. Second, my conclusions have changed from the time I did my original research and paper in 1974.

In my ACSC paper, I concluded that you must have at least one below-the-zone promotion to be promoted to general, which was true then. Today, that figure has gone down. Of the navigator generals, 18 percent have had one below the zone promotion, 18 percent have had

two, 4 percent have had three and 54 percent—more than half—had no promotions below the zone. This was very surprising to me, but it points out again that the young navigator doesn't have to leave the crew force early and get those Pentagon and MAJCOM assignments. I learned an interesting thing when I asked one general if he had any below-the-zone promotions. He said, "Nope, and, as a matter of fact, I was deferred once for major." That fact should mean something to the navigator out there who might now be suffering a deferment. Even though the chances are slim, the opportunity exists. I think our navigators need to know this.

After this review of numbers and statistics about navigator general promotions, I would like to share some of the generals' comments when I asked if they had any message for the folks on the crew force. You don't have to agree with their comments—you may even be a little cynical about some—but, remember, this is advice straight from the guys who have been there.

Major General Larry N. Tibbetts - "The system works, make sure you work. Do the job you have better than anybody ever did it. Look for the hard things to do."

Brigadier General Harry H. Bendorf - "Whenever you compete with someone, outthink him; if you cannot outthink him, outwork him. Make your own opportunities."

Brigadier General Donald W. Goodman - "Do the job you've got the best you can; you will be noticed."

Brigadier General Donald C. Metz - "I believe we've oversold the career development program. Young officers worry too much about what they should be doing next. Best thing to do is concentrate on the job they currently have. Don't try to jockey for position."

Major General James G. Jones - "Get a command job as a major or lieutenant colonel...it doesn't make any difference what type of squadron or unit, just get a command...or be a program manager, or a key staff director. You need to be in charge of something at least by the lieutenant colonel level to continue to advance."

Major General Maurice C. Padden - "Master your nav job to the best of your ability. Volunteer and master (better than anyone else) additional duties. Strive for a secondary specialty because opportunities for command above O-5 are slim as a raw-boned nav."

Lieutenant General Bernard P. Randolph - "Seek leadership roles. You are first and foremost an Air Force officer. Navigator, pilot, engineer, etc. are skill areas only."

Brigadier General William J. Porter - "Seek responsibilities (jobs/projects). Differentiate yourself through hard work and a willingness to work the tough ones—no matter what they are."

Brigadier General Allen K. Rachel - "Be very good at your primary job—then branch out into related fields. Pick an area of interest and pursue it."

I'd like to close this article with a few comments and a little advice of my own. The major conclusion of my research is that I found no magic formula guaranteeing someone could make general. I did find that the 22 who made it did so by doing their assigned jobs to the best of their ability. They did take advantage of opportunities, they did go to the Pentagon, they did go to MAJCOMs, they did have commands, and they didn't all have below-the-zone promotions. (Remember, however, achieving the rank of colonel would be the highlight of a truly successful career. Being promoted to general is not the norm.) My philosophy has always been—"If there is a way to do it, I would like to try it." Opportunities are there and it all starts with doing your best with the job you have. Make your boss look good. Whatever problem your boss has, work it for him; forget about yourself and he'll take care of you.

Get your gates early. If you don't, the Air Force is going to bring you back to get them at a time that may not be to your liking. It is not worth the gamble. Odds are you will do well if you stay and finish your gates. The gamble comes if you have to come back to the crew force. This is probably the hardest point to make to the young navigator and have him really believe it.

Don't get locked into a narrow field of expertise. Go for job diversity. Get that PME and advanced degree. In the long run, this will prove to be cheap insurance. Take an aggressive interest in your own career. Make sure you are prepared when opportunity knocks. Success is never guaranteed, but you can take command of many things that will tilt the odds in your favor. Finally, and most importantly, have a competitive record reflecting sustained superior performance. If your record doesn't surface at selection time, nothing else matters.

WHEN A GOOD SYSTEM FAILS:

Emergency High Bombing with No OAS Data

Captain David A. KARNS
AF/RDQM
The Pentagon

The B-52 offensive avionics system (OAS) is a highly accurate, technologically advanced bombing and navigation computer system. High dependability is attained through multiple avionics processors and inertial nav systems. Perhaps understandably then, interest in any emergency bombing procedures and techniques (e.g., with no OAS data) has declined.

We must be competent in high alternate procedures for several reasons. First, we have the tasking for high altitude bombing. Second, the OAS does fail occasionally. If we are going to fill out a SACF 1040 (OAS bombing data form) with emergency back-up data for a high release, the numbers must not only be correct but also understandable and usable. And, third, for B-52 radar navigators and navigators, bombing is the reason for being. If we lose our detailed bombing knowledge, we will truly reduce ourselves to the dubious status of a "system operator," a condition dangerous for obvious reasons.

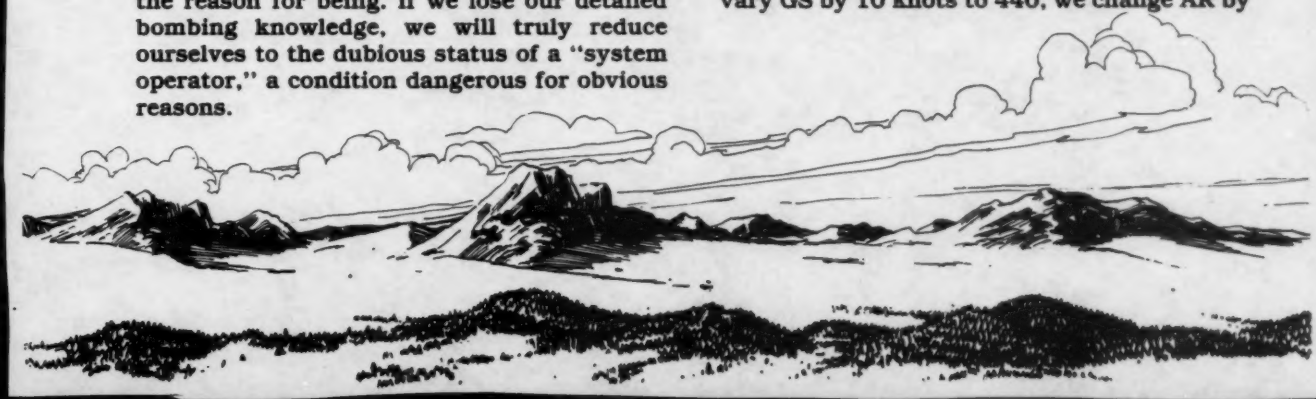
The purpose here is to refresh memories on a few basics related to high altitude no OAS data bombing and to present perhaps a new twist so that all the data we record is correct and usable. We will briefly cover actual range (AR) and the effects on it by the various entering arguments, and the need to convert various numbers from ground to slant range (and back), including the emergency timing point (ETP) offset track/CF-C distance.

To find the bomb release locus (BRL), we compute AR and measure that distance back from the target. (Crosstrail, from the Universal Crosstrail Correction Chart in the 1B-52D-25-10, is applied upwind in-flight.) The formula for AR is: (groundspeed in feet/sec. times actual time of fall) minus trail. Let's examine the entering arguments.

Actual time of fall (ATF) varies mainly with changes in release altitude above burst (RAAB). Trail (L) varies mainly with changes in true airspeed (TAS). Normally, backup timing for a high release is figured using a preplanned RAAB, TAS, and exact groundspeed (GS) off the winded flight plan. And the computed AR is good only for that combination. Spinning the distance to release with other GSs + 30 knots of planned speed, just to fill in blank lines on the 1040, will give erroneous times.

If the exact combination of preplanned values fails to materialize in-flight and you don't have time to recompute, you can minimize the errors by making good the most critical of the preplanned arguments. Altitude normally isn't a big problem, ARTCC vectors aside. Of TAS and GS, we can see which is more critical through an example.

Given: RAAB-35,000', tgt elev. -0', GS-450, TAS-420. Using MB-4 ballistics (since there are no approved BDU-38 high ballistics), if we vary GS by 10 knots to 440, we change AR by



.15 nm; but AR changes only .04 nm for 10 knots less TAS. Given the formula, with GS'/sec factored, this makes sense. So in-flight, fly the preplanned GS if possible to minimize error. So far, nothing really new except that with the SACF 1040, all the ballistics have been shrunk down to one value, AR, a fluid quantity.

The other main arena on the SACF 1040 involves ETP timing computed for the no OAS data scenario. If bombing high with target direct as ETP, there is no problem. Simply set an accurate CF-A (AGL, not MSL), use CF-B as required to display a drift corrected track line, and leave CF-C at 0.0 nm. You'll have a 75 nm ground range scope with fixed range marks (FRM) to initiate timing to the BRL. The 75 nm scope is a bit unwieldy for 20/10 hacks though, so you may want to "lie" to the machine to get a 25 nm/slant range display. Accomplish this by setting 0' AGL in CF-A, or put an offset line in with CF-C while continuing to track the target down the drift corrected track line. Now you have to convert slant range to ground range to figure ground distance to release.

Unfortunately, target direct scenarios are not universal. At high altitude, with CF-A 5000' and CF-C 0.0 up to 20.0 nm, we have a slant range scope. We must now convert all slant range FRM distances to ground to measure distance to release on the 200 series chart, and certain ground measured distances to slant for what we will see in the scope. Thus, if at 36,460' AGL, a return at 20 and 10 nm on a slant scope is really at 19.08 and 8.0 nm in ground range. We find where these ground distances intercept track, measure from these points to the BRL, and spin time to release using the exact GS.

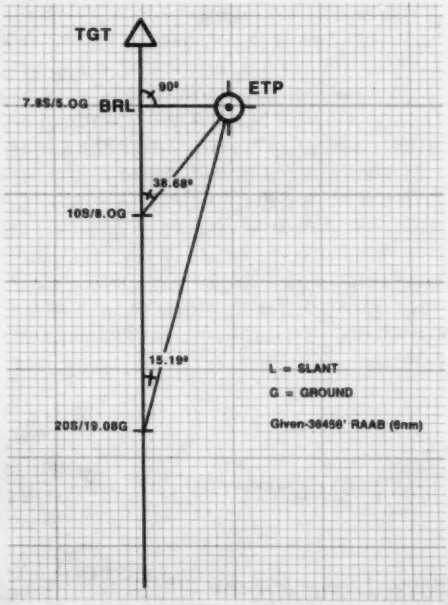
This slant to ground conversion is simple using the Pythagorean theorem in this form: $b = c^2 - a^2$, where "a" is altitude AGL, "b" is ground range and "c" is slant range. All numbers are in nm—easier to manage than feet.

One other value on the SACF 1040 has rendered those correctly converted 20/10 ETP hacks unusable to some degree, depending on the spatial relationship/range and bearing of the ETP to the BRL. This value is the ETP offset distance. Current practice is to measure the perpendicular ground distance from planned bomb run track to the ETP on the 200 series chart and then record that value on the bomb form, + for left and – for right. But why are we using a simple ground distance with slant range FRMs? If we are flying at 6 nm AGL over flat terrain, an ETP measured off the chart at 5 nm right abeam the BRL will not track down a CF-C line set at –05.0. The altitude hole at scope center will have a 6 nm radius. It is clear then that the ETP offset distance must also be converted. Here, however, the conversion is a bit more difficult.

To find the error of the offset track line distance, use this formula: E = SIN(RB)X(GDvsSD). That is, the sine of the relative bearing from planned track to the ETP, times the difference between ground and slant distance at that altitude. This error is added to the measured ETP offset ground distance and set in-flight with CF-C. Since all of the formula's values change as you fly down the bomb run, any final CF-C setting is good at only one point, e.g. the 20, 10 or release hack. And since both the RB and GD vs SD increase as you get closer to release, the error grows continuously until abeam the BRL (or till release). If the ETP is directly abeam the BRL, the error will equal the GD vs SD since the sine of 90° = 1.0. An ETP near this relative position normally has been preferred since the operator could take at least a 20 and 10 nm hack and track the return through release.

Let's examine the impact of changing offset distances on a high altitude bomb run/bomb form. In our example (Fig 1), the ETP is 5 nm

Figure 1



ground distance directly abeam the BRL. Given the RBs at the 20, 10 and release hacks of 15.19, 38.68, and 90°, we take the sine of each to get .262, .625, and 1.0, respectively. The slant vs ground differences at these ranges (again at 6 nm AGL) are .92, 2.0, and 2.8 nm. Multiplying Sin(RB) by respective GD vs SD, we get .24, 1.25, and 2.8 nm of error. Add the error to the measured ground distance to find the proper CF-C settings for the 20, 10 and release hacks; that is, 5.24, 6.25, and 7.8 nm.

Using this procedure in-flight takes a bit of practice. Prior to each planned FRM hack, the corresponding CF-C distance is set. The operator must evaluate his position at the hack and alter (using S-turns, ratio fixed angle, etc.) so the ETP is at the next computed FRM/CF-C line intersection, simultaneously keeping CF-B updated for current drift. Even with no drift and the aircraft on heading and centerline, the unpracticed operator will be tempted to alter unnecessarily. This is because the return will move in a curve on the slant range scope (Fig 2 & Fig 3), moving farther from centerline as the plane flies closer. The observed effect is the same as that from a physical bow wave; the altitude hole pushing returns out and then pulling them back in (at exactly the same rate) after passing abeam. If the ETP offset distance is not converted and the operator attempts to track the return down the CF-C line, he will constantly alter away from the target up to release or until he notices the CF-C line runs through his altitude hole and wonders how to track a return into that!

Figure 3

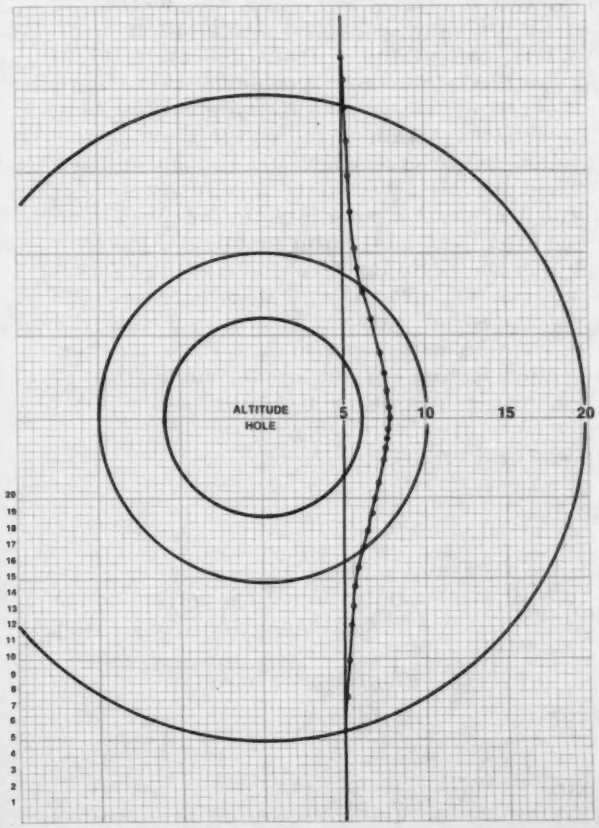
PLOT DATA

rel. bear.°	SIN	slant/ground	dif.	error nm
13.02	.2252	23/22.2	.8	.18
15.192	.2621	20/19.08	.92	.2411
17.136	.2946	18/16.97	1.03	.3034
19.704	.3372	16/14.83	1.17	.3945
23.282	.3953	14/12.65	1.35	.5337
25.7	.4337	13/11.53	1.47	.638
28.766	.4812	12/10.39	1.61	.7747
32.84	.5423	11/9.22	1.78	.965
38.68	.625	10/8.0	2.0	1.25
41.85	.6672	9.6/7.49	2.11	1.41
44.687	.7032	9.3/7.11	2.19	1.54
48.17	.7452	9.0/6.71	2.29	1.71
54.26	.8117	8.6/6.16	2.44	1.98
60.76	.8726	8.3/5.73	2.57	2.24
70.94	.9452	8.0/5.29	2.71	2.56
76.6	.9728	7.9/5.14	2.76	2.68
81.17	.988	7.85/5.06	2.79	2.756
84.5	.9954	7.825/5.03	2.795	2.79
90.0	1.0	7.8/5.0	2.8	2.8

Reasonably then, one of three things is needed: (1) follow the procedure above with several CF-C settings, (2) choose ETPs as close to dead over (vs abeam) the target as possible, or (3) combine one and two. The current practice of using 20/10 slant FRMs with ground range CFCs makes no sense and uses a lot of time in the planning phase (besides being unreliable.)

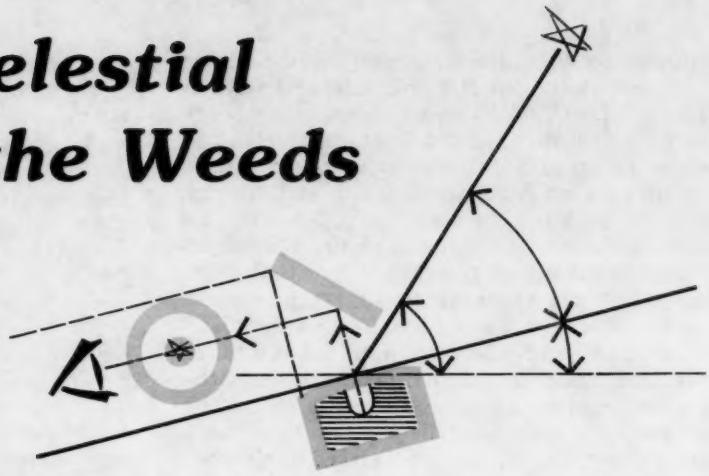
Hopefully, this brief discussion of OAS alternate bombing data, AR, the relative weights of ARs entering arguments, and slant vs ground ranges has sparked some interest and a few questions. Our job is still to bomb, even if a machine can usually do most of the work for us. The difference is—we know what we're doing and it doesn't!

Figure 2



Capt Karns graduated from the University of Cincinnati in 1977. He entered the Air Force via OTS in 1978 and then completed UNT, NBT and CCTS. Assigned to the B-52, he served a 5½ year tour at Minot AFB. Capt Karns currently is an ASTRA officer at the Pentagon.

Keeping Celestial Out of the Weeds



Captain Robert L. DIMMICK
AFIT/ENA
Wright-Patterson AFB, OH

Have you ever had one of those days when you thought you had a perfect celestial position only to find your LOP fell 15 nm from your DR? What caused your perfect celestial position to fall out in the weeds? Probably uncorrected celestial acceleration errors caused your dilemma.

AFM 51-40 explains that any outside force (such as a change in track or groundspeed) affects the liquid in the sextant bubble chamber and thus displaces the bubble. Because the bubble is displaced, the artificial horizon used in the sextant is erroneous and the resultant LOP is inaccurate. This leads us to the conclusion that any change in track or groundspeed during a celestial observation will directly affect the accuracy of the celestial LOP.

Four different types of celestial acceleration errors occur. The two most commonly recognized errors are Coriolis and rhumb line. During celestial navigation we routinely find these errors and apply the appropriate corrections to the LOP. The two other types of acceleration errors are wander and speed (sometimes called acceleration) errors. These two errors cause most bad LOPs because they are routinely ignored and difficult to compute. When you are striving for accurate celestial navigation, however, you cannot afford to ignore these errors. Fortunately, the modern calculator makes the corrections easy to compute.

Now we will get to the heart of this article—correcting your LOP for wander and acceleration errors. These errors have been around as long as the bubble sextant, but very little has been written about them and even less on correcting them. Major Sieverding wrote an excellent article for the Summer 1980 issue of THE NAVIGATOR explaining most of the acceleration error theory and one method of determining wander and acceleration error. While conducting further research, I encountered the same problems that Major Sieverding had; no quantitative solutions exist to determine wander and acceleration corrections, just brief descriptions and disclaimers. Then one day I discovered the elusive wander and acceleration equations tucked away in an old KC-135 CCTS training manual. Apparently, as the accuracy of automated navigation systems such as INS and DNS increased, the emphasis on extremely accurate celestial navigation decreased and these important correction factors slipped into obscurity.

Here are the equations I found:

WANDER FACTOR

$$WF = 2.625 \times \frac{GS}{100}$$

Where WF - wander factor (the correction for 1° track change during a 2 min shot)
GS - groundspeed in knots

ACCELERATION FACTOR

$$SF = \frac{3}{\Delta T} \times \Delta GS$$

Where SF - speed factor (the correction for a change in aircraft speed during the shot)

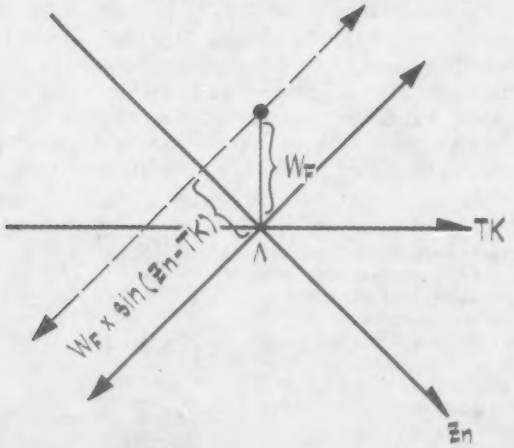
3 - constant
ΔT - shot duration in minutes
ΔGS - change of groundspeed in knots

These two equations provide correction factors that are applied to the LOP by plotting their value either perpendicular or parallel to the aircraft track (plot wander perpendicular and acceleration parallel). But these corrections would be more useful if they were applied directly to the Ho instead of requiring more plotting. So the problem becomes modifying the equations into an Ho correction factor.

WANDER ERROR

Since the wander factor corrects for 1° of track change, it follows that multiplying by the total track change (ΔTK) yields a total wander correction. Also, since the wander factor is based on a 2 minute shot, we can correct for a shorter than 2 minute shot by multiplying by the shot duration divided by 2 ($\frac{\Delta T}{2}$). Finally, to correct from a perpendicular distance to a correction applied to the Ho requires the factor sin (Zn-TK). This gives us:

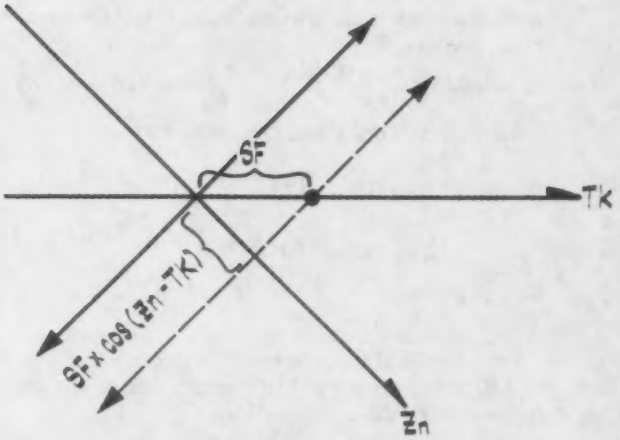
$$W_E = 2.625 \times \frac{GS}{100} \times \Delta TK \times \frac{\Delta T}{2} \times \sin (Zn - TK)$$



ACCELERATION ERROR

The speed factor equation is already in a usable form and only requires correction from a parallel distance to an Ho correction using cos (Zn-TK). This gives us:

$$A_E = \frac{3}{\Delta T} \quad \Delta GS \times \cos (Zn-TK)$$



These two equations are now in a usable form, but we must make a few assumptions. The first is that with perfect collimation during the shot the cumulative wander and acceleration errors are based on the initial and final track and groundspeed only. This implies that if you collimate continuously throughout the shot then any acceleration followed by an equal acceleration in the opposite direction will have a balancing effect on celestial acceleration errors. This idea is comfirmed in AFM 51-40 which states that if the aircraft track and groundspeed are the same at the beginning and end of the shot no wander or acceleration error will occur regardless of the conditions during the shot. The second assumption is that when specific values of track and groundspeed are required, an average value will suffice based on the track and groundspeed at the start and stop of the shot. The need for the assumption arises because the wander correction equation assumes no groundspeed change occurred and the acceleration correction equation assumes no track change occurred. Since track and groundspeed changes usually occur together these ideal situations seldom exist, and thus the necessity of using average track and groundspeed information. So, substituting

average track and groundspeed into the equations we get:

$$W_E = 2.625 \times \frac{\text{Avg GS}}{100} \times \Delta TK \times \frac{\Delta T}{2} \times \sin(Zn - \text{Avg TK})$$

$$A_E = \frac{3}{\Delta T} \times \Delta GS \times \cos(Zn - \text{Avg TK})$$

Where $$\text{Avg GS} = \frac{GS_1 + GS_2}{2}$$

$$\text{Avg TK} = \frac{TK_1 + TK_2}{2}$$

For the final step, we will combine the two equations to create a single correction to the Ho for wander and acceleration:

$$C = .02625 \times \frac{GS_1 + GS_2}{2} \times (TK_1 - TK_2) \times \frac{\Delta T}{2} \times \sin\left(Zn - \frac{TK_1 + TK_2}{2} + \frac{3}{\Delta T}\right) \times (GS_1 - GS_2) \times \cos\left(Zn - \frac{TK_1 + TK_2}{2}\right)$$

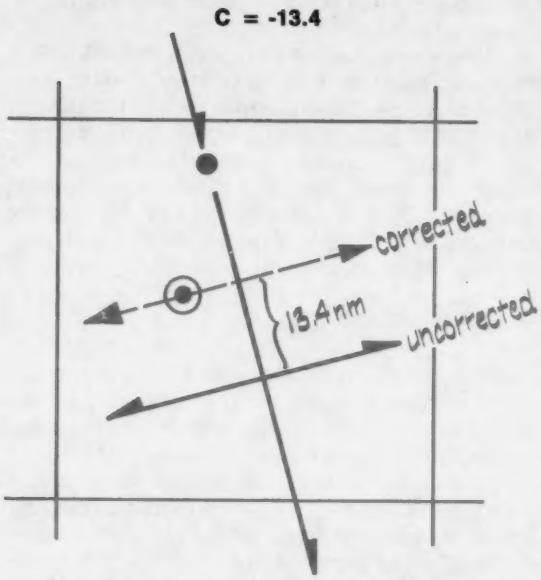
Obviously, this complex equation is not easily memorized. However, with advances in programmable calculators this equation easily can be programmed and used routinely in flight. The other requirement for practical application of the wander and acceleration corrections is an accurate measure of the change in track and groundspeed. This information may be provided by an INS or DNS, or by using the new digital Doppler readouts. Now the only requirement for highly accurate celestial information is recording the track and groundspeed at the start and stop of the shot, and then correcting the LOP for wander and acceleration. Remember, the correction computed with the equation is applied algebraically to the Ho.

Finally, I'm including an example of how acceleration errors affect celestial information. During a celestial observation a wind shift results in a 1° change in drift and a 6 kt change in groundspeed. You also started the shot late and to compensate you have only a 1 minute 30 second observation. Here is the input information:

$TK_1 = 221.2°$ $TK_2 = 220.2°$ $Zn = 169°$

$GS_1 = 384$ kts $GS_2 = 390$ kts $\Delta T = 1{:}30 = 1.5$ min

The resulting wander and acceleration correction is:



As you can see, a small wind shift during an observation can greatly affect the accuracy of the celestial information.

The best way, of course, is to avoid wander and acceleration errors through careful heading and airspeed management. Unfortunately, this is not always possible. In these cases, a little extra effort and a calculator can correct these acceleration errors and enhance the accuracy of celestial navigation—vividly.

Capt Dimmick is a 1978 graduate of the Air Force Academy. After completing UNT and CCTS, he was assigned to the EC/KC-135 at Grissom AFB and also served as a flight examiner. Capt Dimmick now is assigned to Wright-Patterson AFB in the AFIT Program.

Professional Reading

Major Donald W. RIGHTMYER
HQ TAC/SEP
Langley AFB, VA

This invitation to professional reading includes two books: one old and one new. They will both be of interest to Air Force professionals and certainly to the entire USAF navigator community. The more ancient title is *Most Probable Position* (1972) by Dr. Monte Wright, Lt Col, USAF Retired. The second book, nearly hot off the press, is *Flight In America 1900-1983* by Dr. Roger Bilstein of the University of Huston.

Very few books have been written about our aerial navigation heritage and Monte Wright's book, subtitled "A History of Aerial Navigation to 1941," has to rank as one of the best in print. In the first chapter he lays a foundation for any reader to understand where we've come from by examining the basic nature of marine navigation. You'll find that's where many of our basic nav skills have their origin.

As the first practical examples of aviation, balloons also served as the testbeds for finding one's way in the air. Of course, some of the first significant long-range navigation was seen during World War I. Not only were on-board instruments put to the test but also direction-finding by radio aids was used by the Zeppelins on their bombing raids over London.

Aviation saw tremendous development in the postwar period and navigation skills were no exception. One of the driving forces behind that growth was the need to develop overwater routes to carry mail and passengers on the newly developing commercial airlines. Aerial maps for overland flights and celestial navigation, particularly for the overwater routes, also came into their own.

The book's last chapter brings you up to the pre-World War II days. The author sets the stage for the training of both the navigators leading bombing raids deep into hostile territory and those transporting cargo and personnel around the globe. Unfortunately, that's where the book ends. We can only hope that some nav out there will pick up where Dr. Wright left off and bring our story up through the jet and space age.

Flight in America gives a much broader look at the varied aspects of American aviation including civil, commercial, military and aircraft production. It covers each period of our nation's aviation life story from the stumbling days of childhood through the maturity of the space age and the shuttle. The reader will come away with a much better appreciation for both the concept and realities of air power and where we in the Air Force have figured in it.

Roger Bilstein's book should be available in your base library soon or you can have it ordered from the publisher. Dr. Wright's book is already out there waiting.

Grab a good book off the shelf this winter and open your professional horizons a little wider.

The authoritative history of the Vietnam War is currently being published as a multi-volume series by the U.S. Army Center of Military History. These books will be the Army's official account of the war and will vividly record the rising and falling tides of America's involvement in Vietnam.

The series of some 20 books, to be published over a period of 10 years, includes the Army's involvement from its early advisory years to 1973 when the American troops left Vietnam. Illustrations, maps, charts, and photographs are featured throughout the series. Each book in the series will include a comprehensive index covering personal names, military titles, geographic locations, major Army functions, and commands down to the Division level. Special books will focus on the massive logistical support of the war, its pioneering technologies, Vietnamization, intelligence, and communications.

All of these books will be sold by the US Government Printing Office. To receive timely announcements of each volume's publication (as well as notices of new military history books from all of the armed services), send your name and address to the Superintendent of Documents, Mail stop: MK, Washington, DC, 20401 and ask to be put on Priority Announcement List N-534.

a WSO manifesto

Captain Thomas A. FUHRMAN
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Edwards AFB, CA

"Taxi into position and hold.""Let's get this flight airborne," thought Muck, looking over at Slider, his counterpart WSO in the number two airplane. "The sooner we get off, the sooner we get back...Sure wish I'd get my 500 hours so I wouldn't have so many squares to fill...Wish we weren't the lead airplane..."

"Check list!" called the pilot, "Come on, Muck. Get with the program!" "OK, Flash, OK," thought Muck as he mindlessly read the check list. "The program? What is the program anyway?"

CLUEBIRD ON GUARD

Well, Muck, there is a "program," and there's more to it than filling training squares. Remember, as part of the flying Air Force you are a warrior. A combatant. A fighter. That "square-filler" flight is practice for war. Get that into your head. As a WSO you are the expert in the tactical employment of your weapons system. You're ready to go to war, Muck. Your middle name should be Tactics.

KNOW THE ENEMY

One of the imperatives that you as a WSO face can be stated very simply:

Know everything about him; he wants to kill you. Know his aircraft as well as he does. Know his ground threats intimately. How does he employ his weapons? What are his formations, both in the air and on the ground? WHY? When and how does he travel? Where would you expect to find each of his threat systems? WHY? How do his commanders work? What are their priorities and how do they effect command and control? What about the individual enemy combatant—your enemy counterpart? Can you match him in battle? How would you deal with him if you could see the whites of his eyes? Think about these questions, Muck. Think about them in depth. Remember, he truly wants to kill not only you, but also the ideals which you represent.

How's your visual recognition, Muck? Pretty good, you say, but you still can't tell a Flogger from an F-111? How about ground equipment? How about ships? You've got a long way to go, Muck.

"Knowing the enemy" also means knowing how to defeat him. Being able to get through the tactics master question file (MQF) is not the whole story. The MQF will not give you the understanding that concentrated tactics study will. There is no substitute for study, study, and more study. How much time did you spend at your tactics studies last week? You didn't have time? If you think you don't have time for that as a lieutenant, just wait a few years. Believe it or not, that solid base of tactics knowledge you see in your flight commanders, operations officers, and squadron commanders was built while they were lieutenants—not captains, majors, and lieutenant colonels. Now is the time, Muck. It doesn't get any better. Spend another hour or two per week in the tactics vault. You'll be glad you did it.

Are you up to speed on your combat flimsy, Muck? Cramming once a year for your annual certification won't do. You've got to exercise those procedures over and over. Practice the basic procedures on every flight. Those training flights you call "square fillers" can be much more productive, more meaningful, and more rewarding. But you'll have to put forth a little extra effort.

Of course, all the book knowledge in the world won't help *you* if you can't put it to work in the heat of battle. How will *you* fight the war? How will you react if engaged? Well, Muck, use your imagination. One of the best ways to improve your combat survivability is to use your imagination; mentally place yourself in a threat situation. Contrive a tactical scenario, and imagine flying into it. The more detail you put

into the scenario the better. Plan your every move to counter the threat and accomplish the mission.

This idea is not new. World War II P-47 ace Walker M. Mahurin said it well:

> Before I ever saw [the enemy], I used to spend hours just sitting in the old sack thinking up just exactly what I would do if the [enemy] were in such and such a position, and what I would do if he were doing something else. I think that it all paid in the long run. A couple of times I have been fortunate in running into just the situation I had dreamed of at one time or another. Then I didn't have to think. I just acted, because I had mentally been in that very position before. I believe it helped...I know that I don't consider the dreaming time wasted. It's a lot of fun, too.

Rehearse over and over every conceivable tactical scenario. Do it often. Make it a group exercise with your squadron buddies. The more you practice your exact responses, the more prepared you will be when the real situation occurs. And you've got to believe that when the real situation does occur, you'll be the best guy in the squadron to get the mission accomplished.

Maybe you'd rather sit in the squadron with your feet up, coffee cup in hand. You're a flyer though, Muck. If you don't have the terse fury of tactical flying in your blood, then maybe you are in the wrong business. Grow fangs, Muck, or start looking for another job.

"OK, check list is complete," said Muck, stuffing the yellow book in his g-suit pocket. "Hmm...RADAR COMPUTER BIT FAIL" he thought, noticing the illuminated light on the telelight panel. "Wouldn't you know it...Now, what's that supposed to mean to me? Was it '...ranging will be in error...' or '... destruction of some radar components may result if radar transmission is attempted...?' Well, better not ask Flash or he'll come down on me. We'll see what happens when we get airborne."

Muck, you've got problems. Answers to the basic questions about system operation should be part of your nature by now. A young WSO is in a unique position, Muck. You have advantages over a young pilot in that you will be exposed to a greater variety of missions earlier in your flying career. You become seasoned more quickly and are expected to learn more quickly. Your knowledge of all the WSO equipment, the aircraft, and the basic HEFOE systems should be unshakable by the time you have 200 hours. You're not baggage, Muck. Get in the picture.

KNOW YOUR AIRCRAFT

Muck, the second imperative you face as a WSO can also be simply stated.

KNOW YOUR AIRCRAFT

Aircraft knowledge is one of those irreplaceable quantities that you can't fake. There's a big difference between being "pretty sure" and *knowing*, especially if you are airborne when the question arises. You should be the guy who *knows*. You ought to have the numbers at your fingertips i.e., maximums, minimums, pressures, quantities, g-limits, airspeed limits, and AOA limits. You can't afford to be pondering the basics when faced with an unusual occurrence in-flight.

The way to know your aircraft is to immerse yourself in its environment. Fly, fly, and fly. When you are not flying, you should be thinking about flying, talking about flying, reading about flying. There is always something you can improve on. You can always run a better intercept, drop a better radar bomb, fly a better low level. How are your ARA's coming, Muck? You don't like to do them because they always make you look bad? Well, Muck, the only solution is to look that problem right in the eye. Decide to become the best guy in the squadron at whatever you like least. Get hold of the hateful thing and master it, Muck. Remember, you are a warrior; don't let the easy things beat you.

How are your hands, Muck? Been getting much stick time? You ought to get your hand on the pole on every mission, even if it is just for a minute or so. And when you have free time out in the area, don't waste it. Have a profile, a sequence of maneuvers that you put together and carry with you at all times. If the only stick time you get is straight-and-level on cross-country legs, make the most of it. Work at flying precisely. Have you noticed how well an autopilot can fly? You should work at flying even better than the autopilot—and certainly better than the pilot. You won't get good without practice. Don't be embarrassed to ask a pilot *how* to fly. That was part of his training, not yours. Learn how to do the continuous crosschecking that good flying requires. Work at it! You can always do better.

That check list you just stowed in your pocket, Muck—do you know how to use it? How did your last EP simulator go? Don't always be trying to jink out of those things, Muck. They might do you some good some day. Just as rehearsing tactical scenarios will improve your combat survivability, so will simulation solidify your aircraft knowledge.

Muck looked around at the wingmen as the aircraft took the runway. "Now how was this takeoff supposed to go?" he thought. "I'm sure they must have covered it in the briefing. Guess I missed that part. That's pilot stuff anyway...I'll let Flash take care of it."

Muck, you're doing it all wrong.

You're an officer, and as an officer you are expected to take charge, to take responsibility. A flying officer doesn't just accept responsibility when it's handed to him, Muck. He seizes it!

BE A PROFESSIONAL

There is no place in the Air Force for an unprofessional aviator, Muck. A third imperative that a WSO faces is:

Get in there, Muck, and take charge! Don't let things "happen" to you in the flying business. You've got to be a driving force. WSOs can sometimes get lulled into silent complacency because the pilot always seems to be in charge. Well, Muck, a few hundred pounds of JP-4 would be more useful to the mission than a WSO who doesn't have the situational awareness to make the timely comment, the right input, the "good call." In the absence of WSO direction, a pilot has no choice but to do what seems best at the moment of truth. As a result, the myth that "the pilot is always in charge" takes hold. Yours is the quiet voice of reason in the ferocity of the air war, Muck. But your voice must be heard!

How many "unsafe" rejoins have you seen? Have you ever directed the pilot to "Overshoot?" How many times have you called "Knock it off" yourself? How about lost wingman situations? Have you ever directed the pilot to "Go lost wingman?" Did you ever see a pilot enter holding incorrectly? violate an airspace restriction or an aircraft limit? fail to follow an established operational procedure without justification? press fuel or weather minimums on an approach?

A WSO has to be a pretty good diplomat, Muck—able to tell that 1,000-hour fighter pilot that he is wrong, but with the tact to say it in the right way at the right time. If you allow a compromising situation to occur without making a timely input to the pilot, you are reneging on your professional responsibility. Don't let that happen. Make yourself the kind of WSO that pilots like to fly with. Make yourself competent.

The first step is to develop a professional attitude. Commit yourself to disciplined conduct. Professionalism, flight discipline, flying safety, and mission accomplishment always fly as a four-ship. Develop a professional attitude and you'll find it's contagious. We all influence each other, Muck, for better or for worse. This fact often surfaces in small ways; checking your ejection seat puts you in mind of your RTU egress instructor's emphasis on habit patterns. There's that fuel planning rule of thumb you picked up from your last ops officer. The way you fold your map came from your last flight commander. We all influence each other, Muck. This means you influence the rest of the guys in your unit. That's quite a responsibility. Think about it the next time you are tempted to blow off the descent check, press crew rest, or stretch the truth about your late takeoff.

You're a professional, Muck. Cultivate your officership continuously. Demand respect in all you do. You have the advantage of flying with many different pilots—each with a different background and experience level. Your conduct is observed and absorbed by others in your unit. In the same way, you can be the eyes and ears of the ops officer. Your opinion is valuable. So, develop it and don't hesitate to provide it under the right conditions. Did anyone ever ask you whom you think should be the next flight lead? Would you be ready with an answer? What yardstick do you use to judge a good pilot?

Professionalism does not end with engine shutdown. Remember, above all else, you are a military officer. Nurture your professional demeanor in the chairborne tasks as well as the airborne. You may not enjoy being the squadron pubs officer, Muck, but you can take some consolation in the words of Douglas MacArthur: "I'm a soldier and will hold the horse if ordered." Accept unsavory tasks by keeping in mind the big picture of what mission accomplishment demands. And believe that your contribution advances the greater good.

Neither is professionalism just somber altruism, Muck. There's something in it for you. The military is a huge system, and it looks very different from every vantage point. As an officer you are both cog and motor. The more you know about the system, the more valuable you become. Seek out some of the uncommon vantage points. You get to play ground-pounder with the Army this month? That's an opportunity you can make good use of, Muck. Knowledge is power. If you want to command, learn to learn as you learn to lead.

You can try to ignore the professionalism imperative, Muck. You can try to maintain your "gentlemen's flying club" attitude, ignoring the demands of the mission, oblivious to your professional responsibilities. You can probably do that, Muck. You may even get promoted. But remember that you are a warrior. By your choice of profession, you have become different from all the non-warriors of the world. Your dedication to ideals is backed by your willingness to fight to protect those ideals. If war were to start tomorrow, you're ready to be the first one in. Accomplish the mission. Nothing less will do.

Cleared for takeoff, Muck.

Capt Fuhrman graduated from Purdue University with a degree in Electrical Engineering. After completing UNT in 1977, he was assigned to the RF-4C at Bergstrom AFB. Next came duty at Kadena AB, followed by RAF Alconbury. Capt Fuhrman graduated from the USAF Test Pilot School in 1984 and currently serves there as an instructor.

We apologize to the author, Lt Haynes, for our oversight in the last issue. In the article "On Course Rendezvous", we omitted the following computer program written in basic for a Radio Shack TRS-80. Here it is.

```
3520: "B":CLEAR :PRINT "CLOSURE"
3525:INPUT "DME 1=";D1
3530:INPUT "DME 2=";D2
3535:INPUT "AVG GS=";G2
3540:INPUT "DIST. TO NEXT POINT=";R1
3541:INPUT "DIST. TO ARCP=";R3
3545:D3=D1-D2:D4=D3X60
3550:G2=G1-D4:R2=R1-D2
3551:R4=R2+R3
3552:R5=R1+R3
3555:T2=R4/G2X60
3565:PRINT USING "#####.##";"RCVR GS=";G2
3570:T3=DMS T2:PRINT USING "###.###";"RCVR ETE=";T3
3571:T2=T2+1      (To arrive at the ARCP 1 minute after the receiver)
3576:T4=R5/T2X60
3580:PRINT USING "####.##";"GS NEEDED=";T4
```

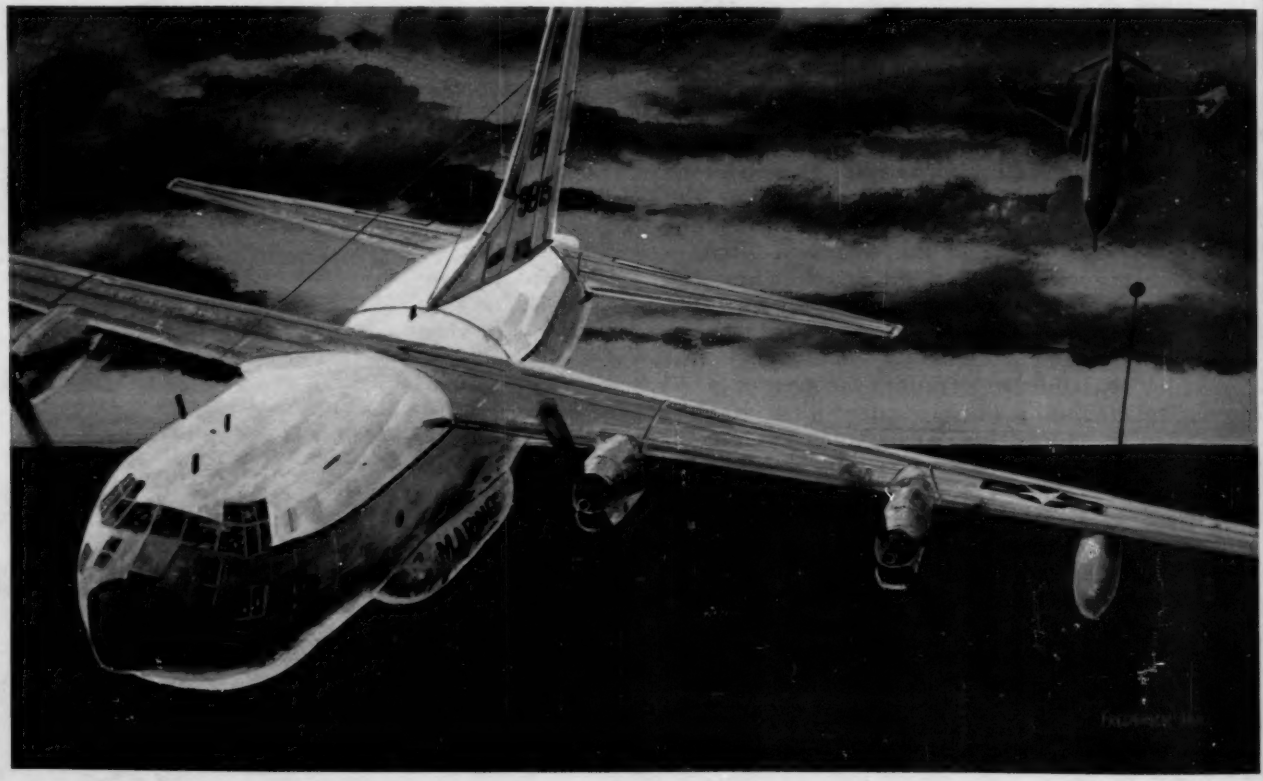
Navigating the Marine Way

Chief Warrant Officer Two William L. SIEBOLD
MANS
Mather AFB, CA

The United States Marine Corps began its long and illustrious history on 10 November 1775 in Tun Tavern, Philadelphia, PA. Created by a resolution of the Continental Congress, the Marine Corps always has played a major part in our nation's defense. Historically, Marine Corps preparedness has been characterized by the phrase, "The First to Fight." Marines are trained, organized, and equipped for offensive amphibious employment and as a "force in readiness." The Marine Corps is equipped to go any place on the globe, at a moment's notice, to fight for freedom wherever the President deems it necessary. In the words of General John A. Lejeune, former Marine Commandant, "The record of the Corps is one which will bear comparison with that of the most famous military organizations in the world's history. In every battle and skirmish since the birth of our Corps, Marines have acquitted themselves with the greatest distinction, winning new honors on each occasion until the term 'marine' has come to signify all that is highest in military efficiency and soldierly virtue."

The Marine Corps basically consists of the ground units and the air wing. Each of these has a myriad of support units attached ranging from administrative to weather forecast personnel. While the infantry does its fighting on the ground, the air wing delivers its punch from the sky. The Marine Corps KC-130 aircraft is an integral part of the overall air-ground team concept. The primary mission of the Marine C-130 is the aerial refueling of Marine and Navy fighter and attack aircraft. However, like its Air Force airlift counterpart, the C-130 may also be called upon for intratheater combat support. The Marine C-130 crew consists of a pilot, copilot, flight engineer, navigator, and radio operator/loadmaster.

As recruiting posters say: "The Marines are looking for a few good men." Presently though, the phrase should continue, "...to go to California to learn the art of aerial navigation." So just what does a Marine aerial navigator do? The navigator plans the navigational phase of the mission. He attends briefings to obtain information on the type of mission to be performed and the conditions under which it must be accomplished. He prepares detailed navigation



flight plans based upon the latest available weather and intelligence information. He obtains navigational data and equipment such as maps, charts, flight publications, and navigational instruments needed for the mission. He navigates the aircraft to accomplish the mission. He identifies drop zones on missions involving aerial delivery of combat troops or equipment, and rendezvous areas for air refueling. He furnishes the pilot and other crew members with information on headings to be flown, estimated times of arrival, current positions, wind direction and velocity, and groundspeed. The navigator maintains flight logs, records, and assigned maintenance reports.

Now just what does all of this mean to the professional Marine navigator? It means that when he receives the call from operations he will go to work. For instance, let's say operations calls and says, "Monday morning we are leaving out of El Toro to move (transpac) a squadron of F-4s to Iwakuni, Japan. Plan the flight, the rendezvous for refueling, and the return flight." At this time the transpac planner, who is a fully trained squadron navigator working in the operations section, swings into action. He contacts the appropriate agency, i.e., the central altitude reservation facility, to reserve the routes and airspace across the Pacific necessary to complete the complex aircraft movement and refueling mission. He coordinates all aspects of the mission including contacting the F-4 fighter squadron to ascertain the number of aircraft to be moved and their fuel requirements. This information is put in message and request format and then sent to all concerned.

Early Monday morning, the navigators assigned to the flight arrive at base weather for an up-to-date weather briefing and spin their winds to determine en route times and fuel requirements. They then perform all preflight duties and board their respective KC-130 tankers and prepare for a precisely controlled take-off time.

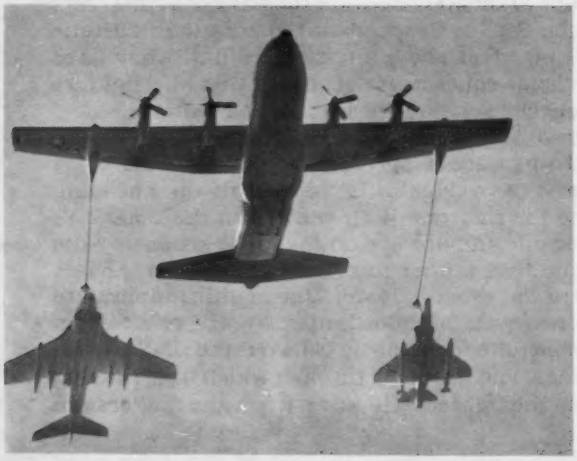
Upon arriving at the first air refueling control point (ARCP), the navigator notes the weather so he can pass it on to the fighters at a later time. He arranges hose assignments for the receivers, updates the winds, and attempts to contact the first wave of six F-4s now en route from El Toro to Iwakuni, Japan, via Hawaii, Wake, and Guam. Upon initial contact, the navigator positively identifies the fighters and requests their altitude, TAS, and ETA to the ARCP. After receiving this information, he begins planning the rendezvous turn for the refueling operation.

Once the fighters have flown within 200 nm of the tankers, the navigator instructs them to dial in 92 on their TACANS and the tankers switch to 29 (a 63 channel separation, 29-92 being easy to remember) and requests that the F-4s give a "short count." At this time, the VOR needle points to the fighters, and the navigator on board the KC-130 gas station passes the tankers' bearing to the F-4s and begins the precise vectoring and timing process so the fighters and the tankers both arrive at the ARCP at the air refueling control time. Aided by the ever closing DME and also positively identifying the fighters on his radar scope at this time, the navigator gets a series of "bearings and plots." He requests that the F-4s fly appropriate headings, keeping them at a 13 nm offset, since that is the radius the KC-130 will travel when making its final rendezvous turn to roll out one mile in front of the receivers. By this time, the four tankers have completed their final orbit, extended their hoses, and are heading directly at the six fighters with a closing speed of approximately 750 kts. Finally, at approximately 50 DME the navigator instructs the F-4s to descend and maintain an altitude 1,000 feet above the tankers until they have visual contact. He requests that the fighters check to ensure "noses cold and switches safe," and that their altimeters are set at 29.92. Things are happening very fast at this point and the navigator is passing his final heading to the fighters. With one eye on the DME VOR needle and one eye on the radar scope he calls the lead tanker to commence the rendezvous turn at exactly 34 nm. During this four minute one-fourth standard rate turn, the rendezvous controller constantly calls out the DMEs, bearings, and headings through which he is passing so the fighters will know when the tankers are

approaching the predesignated refueling heading. At about 10 DME, the F-4 flight leader will spot the KC-130 formation and call "visual contact." Now the rendezvous controller's job is almost complete. The radios are then turned over to the refueling area commander and he does his part in the refueling scenario. This includes clearing the receivers to the "stabilized" position and subsequently to "plug." He, assisted by the Marine flight engineer, then effects the actual transfer of fuel from the tankers to the receivers. The navigator is still busy, however, computing abort times and end of air refueling times and coordinates. These must be monitered constantly because if the receivers are not taking fuel by the abort point they must return to the departure airport and the mission is slid, normally for 24 hours, depending on the number of receivers not getting through. The KC-130 is probably in a TOBOGGAN, i.e., nosed over to gain all airspeed possible to help the now heavy receivers stay airborne. The BINGO fuel, which is the fuel necessary for the tankers to return to the departure airport or to their subsequent destination, is also calculated and monitered by the navigator.

Yet, there is still more to do. The navigator must now work out the drop point coordinates and attempt to get the fighters' clearance to their next destination.

Once both refueling evolutions are complete, the tankers turn and head for Hawaii for some liberty/crew rest, and to prepare to do it all again tomorrow. The overall operation involves 12 fighters, 8 refueling tankers, an airborne standby tanker, a Coast Guard or Air Force bird, 2 maintenance planes, and over 150 crewmen and maintenance personnel. Mounds of paperwork must be completed as well as hours of planning and coordinating with the squadrons. Additionally, transportation, quarters and meals at the advance bases must be scheduled.



When a mission of this magnitude comes off without a major hitch, all Marines involved get a deep sense of pride and a feeling of great satisfaction for having completed a "job well done." Where do the navigators receive the knowledge necessary to carry out these tasks? Most are young enlisted Marines directly out of boot camp. They are sent to NAS Memphis, Tennessee, for aviation classification. Some, on the other hand, enter the field laterally from another occupational specialty, either as a reenlistment option or through a formal request for navigation. All, however, are volunteers. Those who meet the basic mental (GCT 120) and physical (flight physical) prerequisites, then face a rigorous week-long screening process. Screening is given at NAS Memphis, by Marine Navigation School personnel. The applicants who meet the exacting Marine Corps standards are then assigned to the navigation school at Mather AFB.

The Marine Aerial Navigation School's mission is providing academic, simulator, and flying training in fundamental navigation skills to selected enlisted personnel for the Marine Corps KC-130 program. The training course at Mather AFB is one of the most strenuous the Marine Corps has to offer. The syllabus of instruction, which is similar to the Air Force

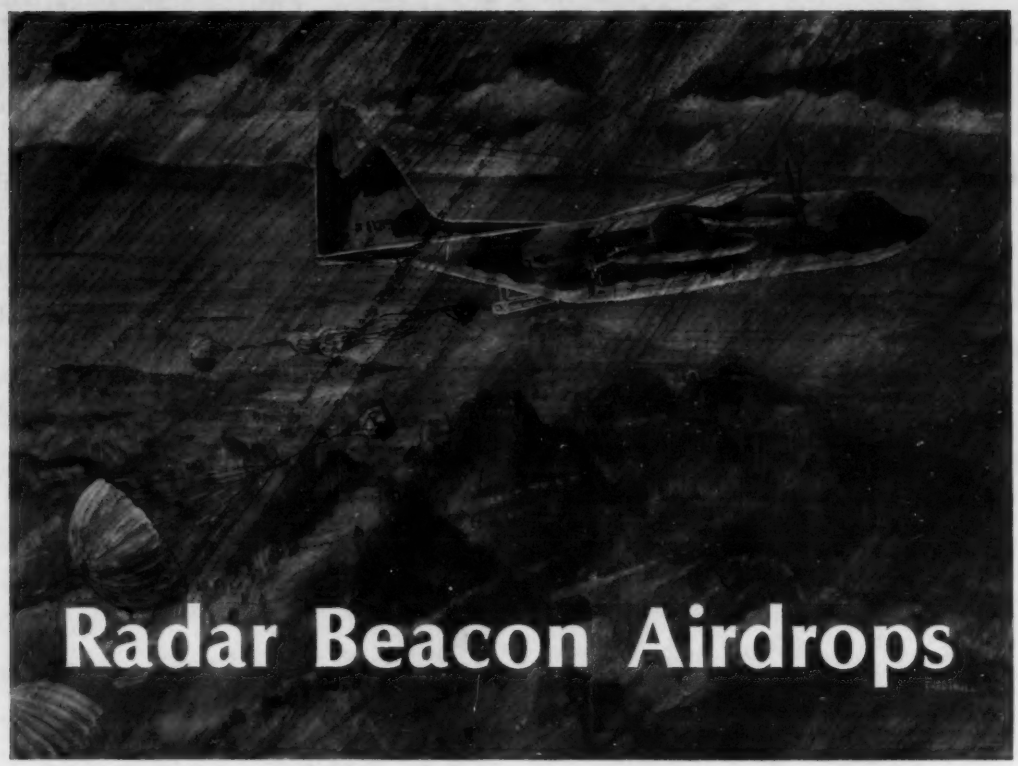
Undergraduate Navigator Training (UNT) program, lasts approximately six months. Academics include aerospace physiology, basic dead reckoning, mission planning, basic navigation, radar navigation, departures and arrivals, T-43 emergency procedures, Loran navigation, weather, day and night celestial, pressure differential, and KC-130 operational systems. While at Mather the navigation students will fly 13 T-45 simulator missions and 14 actual flights in the T-43 aircraft. Except for aerospace physiology, all navigation instruction is taught by Marine warrant officers and noncommissioned officers.

To be retained in the Mather navigation program, Marine students must maintain the highest degree of academic excellence. Additionally, they must remain in top physical condition and uphold the traditional standards of exemplary military appearance.

The Marine Aerial Navigation School supplies all of the navigators for the three active-duty Marine KC-130 squadrons. The Marine graduate remains in a student status in his new squadron until he gains the needed proficiency to pass a "first navigator" check ride given by a squadron NATOPS evaluator. Presently approximately 100 Marine navigators are assigned to KC-130s. (The squadrons are located at MCAS Cherry Point, North Carolina; MCAS El Toro, California, and MCAS Futenma, Okinawa).

The navigation school has gone from strictly a ground school environment during World War II to the present sophisticated training program. The navigator training program is long and arduous, and not all of those who start will finish. However, the United States Marines are a proud group and the Marine navigators are no exception to the rule.

CWO-2 Siebold enlisted in the Marine Corps in 1964. He served in Vietnam during 1965-1966, followed by Okinawa and California. After navigator training in 1976, he served in Okinawa, North Carolina, and California. In 1983, he received a BA from Chapman College. CWO-2 Siebold now is an instructor at Mather AFB.



Radar Beacon Airdrops

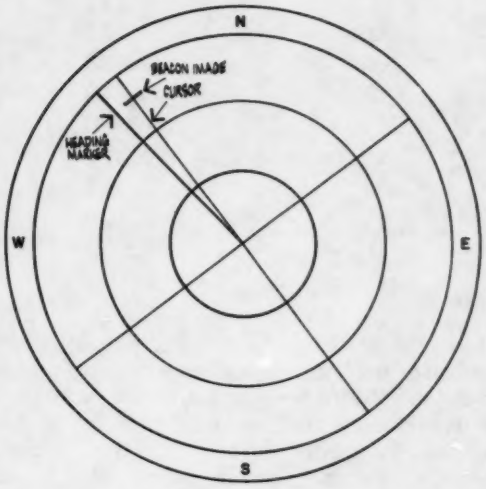
Major Errol L. REKSTEN
62 TAS
Little Rock AFB, AR

Combat airdrop capability provides a means of emergency resupply, launching airborne assault operations, and supplying troops in areas where conventional logistics capabilities are not available. To be truly useful, airdrops must be possible in all weather conditions. MAC C-130 tactical airlift aircraft are not equipped with adverse weather aerial delivery equipment but accomplish airdrops, regardless of weather, by employing the SST-181 radar beacon transponder. Two radar beacon transponders are placed on the desired point of impact, and the aircraft is directed to the release point using the APN-59 Navigation Radar and APN-147 Doppler radar system. Two transponders, one tuned to 9362 MHZ and the other tuned to 9380 MHZ, are required to insure a response to the APN-59 signal. The SST-181 has been in the inventory since the 1960s. In the past, the accuracy of radar beacon airdrops was not satisfactory. Now, however, radar beacon airdrops accuracy nearly equals that of visual airdrops.

This success has been achieved by integrating the Computed Aerial Release Point (CARP) and radar beacon procedures. CARP procedures, as described in MACR 55-40, determine the location of the desired release point—yards left or right of drop zone centerline and distance/time from the closest usable radar range mark prior to the beacon. The signal from the APN-59 Navigation Radar interrogates the SST-181. When interrogated, the SST-181 returns a signal to the radar that is displayed as a single pulse (Fig 1) or a double pulse on the radar indicator. In the double pulse mode, the second pulse will be located at a selectable distance beyond the first pulse, providing an identification capability. The inner pulse reflects the actual distance to the beacon. The navigator uses the beacon image as a terminal reference and directs the aircraft to the release point by providing headings to the pilot. Navigators basically perform an airborne radar approach to the release point.

Successful beacon airdrops start with completion of a MAC Form 512, Computed Air Release Point Computations (Fig 2). Data items are marked to show their source. Drop altitude is determined by plotting the run-in course on

BEACON
Figure 1



EXAMPLE OF CARP COMPUTATIONS
Figure 2

COMPUTED AIR RELEASE POINT COMPUTATIONS

DATE

NAVIGATOR'S NAME (Print): CALL SIGN: ORGANIZATION: NAVIGATOR'S SIGNATURE:

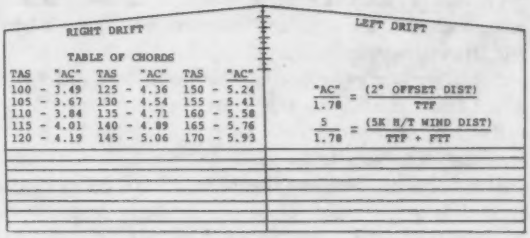
	FACTORS		STANDARD AND MODIFIED COMPUTATIONS
1	DROP ALTITUDE		2795
2	TERRAIN ELEVATION	+	118 *
3	TRUE ALTITUDE		2913
4	PRESSURE ALTITUDE VARIATION	+/- A	0
5	PRESSURE ALTITUDE		2913
6	CORRECTED DROP ALTITUDE	B	2882
7	TERRAIN ELEVATION	+	118 *
8	INDICATED ALTITUDE		3000
9	TRUE ALTITUDE TEMPERATURE		0
10	IAS/CAS/EAS		130/132 **
11	TRUE AIRSPEED		136
12	RATE OF FALL		70.8 * *
13	ADJUSTED RATE OF FALL	C	70.8
14	ALTITUDE ABOVE POINT OF IMPACT	D	2795
15	VERTICAL DISTANCE	=	725
16	STABILIZATION ALTITUDE		2070
17	TIME OF FALL	E	29.2
18	TIME OF FALL CONSTANT	+	7.6 * *
19	TOTAL TIME OF FALL		36.8
20	BALLISTIC WIND		L/V
21	DRIFT EFFECT	F	-
22	DROP ALTITUDE WIND		-
23	MAGNETIC COURSE		338 *
24	DRIFT CORRECTION		0
25	MAGNETIC HEADING		338
26	GROUND SPEED		137 * *
27	EXIT TIME		4.1
28	DECELERATION (NOTIENT	+	3.3 * *
29	FORWARD TRAVEL TIME		7.4
30	FORWARD TRAVEL DISTANCE	G	570
31	STOP WATCH DISTANCE		
32	STOP WATCH TIME	R	
33	USABLE DROP ZONE LENGTH	I	950 *
34	USABLE DROP ZONE TIME	H	
35	RED LIGHT TIME (32 KIAS IAS)		

			STANDARD AND MODIFIED COMPUTATIONS
PREFLIGHT ALTIMETER SETTING			29.92
DROP ZONE			YOJU Weak
SCHEDULED DROP TIME (+)			N/A
LOAD			CDS
LOAD WEIGHT			1600
PARACHUTE (Type and number)			26Ft Ring Slot
FLIGHT STATION OF LOAD			737
FORMULAS	A		29.92 / 0
	B	Temperature / Pressure Altitude	Drop Altitude (Corrected Drop Altitude)
	C	Average Temperature / Average Pressure Altitude	(Adjusted Rate of Fall) / Rate of Fall (DENSITY ALTITUDE MINUS)
	D	Time Altitude	2913
		Meteo Point of Impact Elevation	118
		Altitude above Point of Impact	2795
	E	Adjusted Rate of Fall / Tabulation Altitude	(Time of Fall)
	F	Total Time of Fall (Sec)	(Bolt Effect) Roll Speed
	G	Groundspeed (Kts)	(Forward Travel Distance) Forward Travel Time
	H	Groundspeed (Kts)	Distance (Time)
	I	Usable DZ Boundary (Ft to TE)	950
		Meteo Safety Zone Distance	0
		Usable Drop Zone Length	950
WIND DATA		SURFACE WIND	
		MEAN EFFECTIVE WIND	
		ALTITUDE WIND	
DROP DATA		BALLISTIC WIND USED (M) (D)	DATA DERIVED FROM
		GROUND SPEED (K) (Kts) (S)	* Drop Zone Survey
		DRIFT (L) (Rt) (S)	** MACR 55-40
		GREEN LIGHT TIME (S) (K)	*** MACR 55-130
		RED LIGHT TIME	
RESULTS		TOT	
		FORMATION POSITION (S) (K)	
		RAD CIRCULAR ERROR	
		CORRECTED CIRCULAR ERROR	

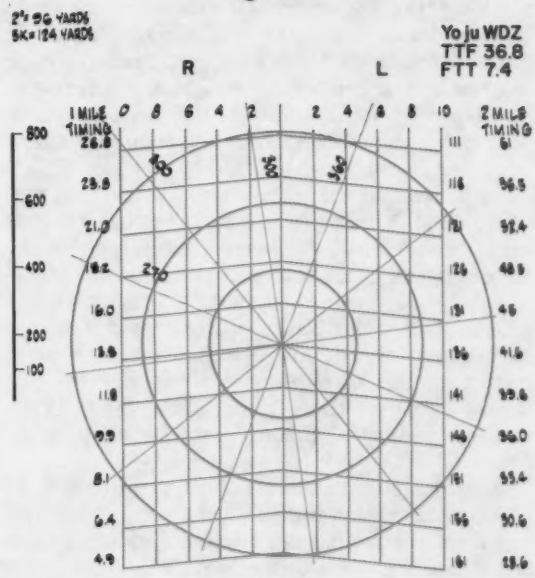
AAC FORM 512 REPLACES MAC FORM 512 DEC 71 WHICH IS OBSO. FTU AND MAC FORM 853 JUN 76 WH CH MAY BE USED

an appropriate chart, locating the high terrain, and adding the desired terrain clearance to the high elevation. The result is entered in block 3. Other data are calculated using common practices and the formulas printed on the Form 512. These data are used to calculate a 2° offset distance and 5 knot headwind/tailwind distance from the formulas printed on the grid overlay plotter (Fig 3). This plotter is issued to all tactically qualified navigators. These data enable the navigator to construct a radar beacon CARP graph (Fig 4). The grid overlay plotter and dividers are used to draw the graph. The centerline of the graph corresponds to the zone centerline. The numbers along the top are degrees of drift. R and L indicate that, with right drift, the aircraft must be left of the drop zone centerline so the wind drifts the load to

GRID OVERLAY PLOTTER
Figure 3



RADAR BEACON CARP GRAPH
Figure 4



HVCDS
1600 lb
26 Ft Ring Slot

centerline. With left drift, the opposite offset will be required. Wind circle diameters are calculated using formula F from the MAC Form 512. Time calculations are accomplished from the last two usable range marks prior to the beacon. Time calculations are started by calculating the time for the no headwind/tailwind case.

The following yields the no headwind/tailwind distance:

2,025 yards per nm times nm from range mark
— Slant range error from MACR 55-40
— Beacon delay (166 yards for the SST-181)
— No wind Forward Travel Distance
— No headwind/tailwind distance

This distance is used to calculate time using formula H from the MAC Form 512. For headwind calculations, (groundspeed less than TAS) the previously calculated 5 knot headwind/tailwind distance is added to the no headwind/tailwind distance for each 5 knots of headwind. For tailwind components, the distance is subtracted. The distances are converted to times using formula F from the MAC Form 512. Plotting either a wind or the drift and groundspeed on the graph provides distance left or right of centerline and time from the last two usable range marks.

Along track position is located by stopwatch timing from the last usable range mark. Crosstrack positioning is accomplished by using the size of the beacon image as a reference. With proper gain settings, the beacon image size is 3°. The 3° beacon image occurs because of radar beam width error.

In the beacon mode the radar antenna rotates at 12 RPM. Timing for along track positioning must be started as the beacon image crosses the inner edge of the last usable range mark. To accurately determine when the beacon image crosses the range mark requires "sector scan." In "sector" the radar beam passes the beacon each time the antenna passes through the 90° sector, rather than once each 360°. This reduces potential timing error by a factor of four.

Operating in "sector scan" produces a 6° composite beacon image. It consists of a 3° image from the right scan portion and a 3° image from the left scan portion. The beacon is physically located in the center of the beacon image. The 6° beacon image corresponds to the physical sizes shown.

RANGE IN NAUTICAL MILES	BEACON IMAGE SIZE IN YARDS
1	212
2	424
3	636
4	848
5	1,060
6	1,272
7	1,484
8	1,696
9	1,909
10	2,121

In-flight procedures are straightforward. The navigator determines a drop wind and plots it on the graph. He determines offset in terms of yards and along track location in terms of time. He then essentially performs an airborne radar approach to the release point. The known beacon image size serves as a reference to allow him to direct the aircraft to the correct offset location. For example, if an offset of 300 yards left is desired, at 6 miles out, the radar cursor should intersect the left quarter of the beacon image. At 3 miles out, the cursor should be aligned with the left edge of the beacon image. Timing, for along track positioning, is started when passing one of the last usable range marks. When the time runs out, the navigator initiates release of the load. The 374 TAW crews have accomplished more than 150 successful beacon airdrops during the last two years. For a properly trained crew, all weather drop capability can be a reality using the beacon. There are other, high-tech IFR airdrop methods. Until some of the more advanced equipment comes into the inventory, beacon drops provide the most flexible and accurate means available in the Pacific theater to perform IFR airdrops.

Maj Reksten graduated from the University of Wisconsin in 1966. After UNT, he served in the C-130 in Taiwan and Dyess AFB. Next came duty at Mather AFB, before his selection for AFIT. In 1974, he obtained his MS in Mechanical Engineering from the University of Arizona. He then served tours at Eglin AFB, Dyess AFB, and Clark AB. Maj Reksten now is assigned to Little Rock AFB.

Weather Avoidance

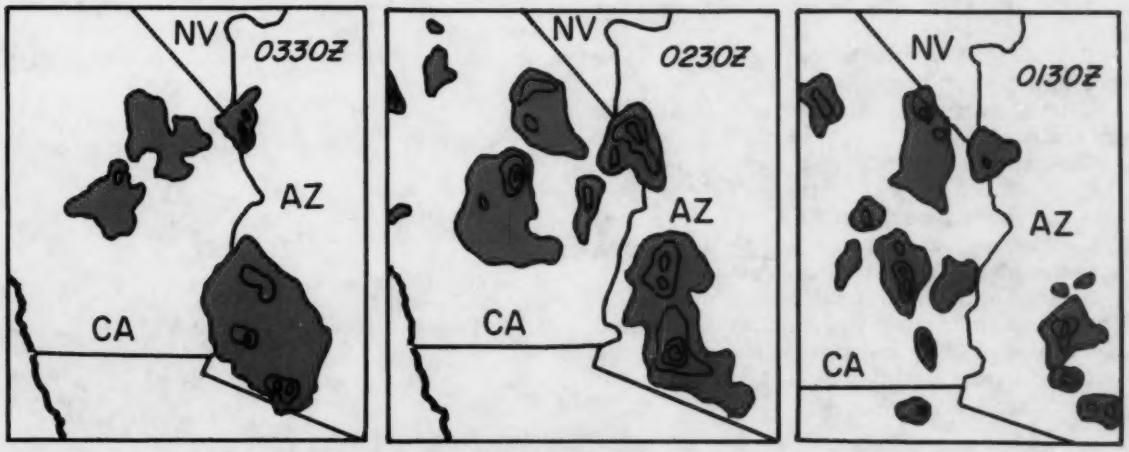
First Lieutenant Bruce A. PRENTICE
22 AREFS/DO
March AFB, CA

At nav school, the students' first exposure to weather and weather avoidance techniques is the T45 simulator. Remember how you always knew exactly where the thunderstorms were located? Well, since nav school I have spent a year diverting around weather in the southwest US, usually with only an approximate location of them. Although the techniques for accomplishing weather alters are the same, a review of some general techniques may improve your chances for mission completion during those hot summer months.

AFR 60-16, p. 5-22 states, "There is no peacetime mission that requires thunderstorm penetration." It further states, "Do not take off, land, or fly an approach at an aerodrome if thunderstorms are producing hazardous conditions. Such hazardous conditions may include hail, strong winds, gust fronts, wind shear, heavy rain or lightning."

The best time to analyze your situation and begin to formulate a game plan is before your flight. Contact the weather shop for forecast conditions on the day of the flight. The forecaster can provide general guidelines for planning your route of flight. Assess all available options, i.e., where to plan your nav leg to best avoid areas of probable thunderstorm activity and how to work your air refueling if thunderstorms are present or the receiver has to come in off track. Evaluating all your options on the ground is time well spent should you encounter thunderstorms enroute.

During the weather briefing, ask the forecaster to review current weather charts and summaries to best determine a plan of attack for weather avoidance (i.e., surface prog, radar summary, surface analysis, etc.). You should plan your altitudes for the mission to avoid the freezing level, if possible (most lightning strikes occur near the freezing level). If base weather has ground radar, also check the departure route and local area to determine intensity range and altitude of weather systems.



The radar summary chart will depict the distribution and give detailed information on precipitation patterns. From this, you can learn echo location, surface weather and intensity, vertical extent, and movement. By looking at past radar charts you can get a feel for cell development, as the previous figure suggests.

By combining this with the surface analysis chart you can determine if any of the cells are associated with a front (possibly a squall line). The surface prognostic chart can help predict areas of precipitation and turbulence.

Now you are ready for flight. On your chart, lightly outline the areas of forecast thunderstorm activity and radar echoes. During your flight, use all available means for avoiding weather. You can set up your radar for weather avoidance by:

1. Setting your radar to 100/20 range. Using longer ranges gives more time to evaluate the weather and take steps to avoid it.

2. Properly positioning the function switch. Check your tech order since the position varies with the aircraft. On the KC-135, it should be in the Search or Warn position.

3. Setting the antenna pattern switch to pencil. This provides a narrower beam with returns more representative at your flight level.

4. Adjusting gain to optimum setting to avoid a high gain or "washed out" scope.

Don't forget the pilot's ability to look out of the cockpit to avoid thunderstorms. Many times the KC-135 radar will not pick up thunderstorms the pilots are looking at out front. Also, talking to the FSS and ARTCC may give you a better picture of what is ahead. Although ARTCC radar is not set up specifically for weather detection, exercise caution if they are painting weather.

Some characteristic weather radar returns are:

1. Areas of precipitation having a fuzzy presentation on the radar scope.

2. Bright returns indicative of precipitation intensity.

3. Shadows which persist behind weather returns at or near your altitude, if the tilt setting is properly adjusted.

4. Shadows that shorten slowly indicating massive, dense and intense weather.

Because of radar attenuation, you may not be able to paint thunderstorms that are behind each other. This consideration should be weighed before deciding or picking your way around large groups of thunderstorms (see illustration below).

Don't get trapped with no way out! All other navigation activity is secondary to avoiding thunderstorms. Don't let your pride and ego adversely influence your decision to takeoff or land in marginal weather conditions. Do not hesitate to cancel a nav leg, air refueling, or any other mission requirement when existing weather conditions would preclude safety.

Thunderstorms are unforgiving! The shortest way through a thunderstorm is around it. Careful planning and knowledge of procedures and equipment will help make your flight safe and successful.

Lt Prentice earned a degree in Business Management and his commission via ROTC at Mississippi State University. He then completed UNT and CCTS. Lt Prentice now serves at Castle AFB.

NAVIGATION: *An Ancient Blend of Art and Science*

Dr. Dallas R. BLEVINS
University of Montevallo
Montevallo, AL

INTRODUCTION

The navigator plys an ancient trade. The aerial navigator must find his way faster than his landlocked or seaborne predecessors, but his quest is the same.

Navigation consists of two requirements. The first is discovering the radial that will lead to the destination. The second requirement is that the radial selected be a safe one to follow. A multi-legged journey is simply a series of radial-destination combinations.

Another consideration is determining the position intermediate to a destination. Position is always useful in record keeping, and often a valuable input in the radial selection phase, but it is not a navigational requirement. Position, however, should be mentioned in any discussion of navigation.

THE RADIAL TO A DESTINATION

A radial consists of direction and distance, with direction the more important. Without knowing the proper direction to go, the probability of reaching the destination would approach zero.

The first navigator in recorded history knew this. About 2500 BC, Noah sent out a raven once a week for an unspecified period to see if the water had abated. He then switched to a dove. The last three of these flights are recorded in sufficient detail to allow an analysis.

Noah selected land birds for a specific reason. When the dove, like the raven before her, could find no rest, she was forced to return to the ark. The bird's return told Noah that the water still prevailed.

On the next to the last recorded flight, the dove returned with a freshly picked olive leaf in her beak. The dove with an olive leaf has come to be an almost universal symbol of peace—and so it was to Noah. Her return to the ark told him not only that land was visible but also that it was supporting plant life. More important, for the purpose of this inquiry, Noah noted the direction of her return. He knew in which direction the destination lay. Further, he had an estimate of how far a dove can fly, so he knew the land's maximum distance from the ark.

When the dove was released the next week, Noah noted the direction of her departure. Although the dove never returned to the ark, she pointed the way to land. If Noah had any estimate of his drift, he also had a good idea of the distance to land.

Noah's triangulation method is still in use 4,500 years later. The location of new radar sites can be fixed by passive reconnaissance aircraft. The electronic ferrets parallel foreign borders in international airspace taking bearings off the radars. Only two such bearings are needed, together with the heading and distance between cuts and the latitude of the surveillance aircraft at the time of one of the observations.

Semitic herdsmen relied heavily on the winds to aid their navigation about the trackless, shifting deserts of the Middle East. These nomads learned to tell direction from the temperature and humidity of the winds.

Before congestion imposed airspeed and airspace limitations, pressure pattern flying was used. Just as the Bedouin knew which direction to drive his flocks and herds from the fingerprints of the winds, so the transoceanic navigator of yesteryear was able to direct his aircraft. In the northern hemisphere, a falling barometric pressure indicated the presence of counterclockwise winds. Thus, a turn to the right would put the low on the left and the wind at the back of the aircraft. The old piston-engined airplanes of the late 1940s through the 1960s used to hitchhike the winds all over the ocean. They were often hundreds of miles off a great circle en route, but were slicing hours off the elapsed time.

At the time the Arabs were conquering the deserts, the south sea islanders were making the vast Pacific ocean their private lake. They used Noah's technique of shore sighting birds. In addition, they noted an absolutely priceless phenomenon: the counterswells radiating from the islands.

Much as concentric circles radiate from a rock thrown into a body of water, the counterswells move outward from the islands. The Polynesian navigator noted that they conformed to the shape of the islands from which they sprang. Both promontories and lagoons offered a special benefit. These island features caused the counterswells to break or burble, thus producing a series of eddies reaching outward from the island.

Although the eddies can be clearly seen from the air, stretching outward for as much as 20 miles, the Polynesian had a perspective of only a few feet. The winds further compounded his difficulty by superimposing waves.

In the daylight, the south sea island navigator performed an operation similar to that used later by aerial navigators doing a radio range orientation, By the mid-1960s most ranges in this country were decommissioned, but they had been the primary means of radio navigation for a generation. The range legs consisted of blending an N(—.) and an A(.—) signal. Like the eddies off the islands, the radio range legs were not always mutually perpendicular.

Flying the range orientation was much easier than the orientation performed in the canoe or sailboat. First, there were only four sectors to a radio range. Two of these were N quadrants and two were A quadrants. Second, the precise station could be identified by its call letters. Third, the width of the range leg could be timed to determine whether a close-to-station or distant orientation should be accomplished. With none of these aids, the Polynesian turned immediately to stay in the eddie. If the eddie got stronger, he stayed on course. If the eddie waned, he turned around. Such a procedure is inefficient, but effective. Aerial navigators used precisely this procedure tracking inbound on low frequency radios using the "loop" position through the late 1960s.

What the south sea islanders lost during daylight operations, they more than regained at night. The eddies lit up. More specifically, the eddies, which were always luminous, could be seen at night. This curious phenomenon was the result of the eddies' stirring the microorganisms in the sea, and their outbound movement lining them up. Thus, at night the Polynesian navigator enjoyed the same quantum simplification experienced by the aerial navigator with the advent of ADF, VOR, GCI/ASR, GCA/PAR, and ILS. •

The Phoenicians became the masters of the Mediterranean during the time of the Assyrians and did not relinquish their dominance until the time of Alexander the Great, close to 300 years. Many of their navigational techniques remain unknown. One contribution, however, appeared around 600 BC which was well published. They placed fires at the entrance to their ports to act as signals to their shipping. In daylight the fires were smothered to give smoke, while at night the flame was exposed as much as possible.

Aerial navigation was enhanced in the 1920s and 1930s by placing lights along designated airways. Although electronic aids soon replaced these, the lighthouse concept remains in service to this day. The green rotating beacon at land bases is just such a signal. The amber light is for seaports. The white light is for civilian and split-white for military installations. Signals from the tower, approach lights, VASI lights, runway lights, taxiway lights, follow-me vehicle lights and parking wands are other current examples of this concept.

The mag compass has been in use since Pythagoras introduced it around 300 BC. The modern navigator still uses the standby compass—essentially unchanged in 2,300 years. The heading indicator is now the primary source of heading information. It is but a gyrostabilized magnetic compass (unless the navigator is flying GRID).

The second part of a radial is distance. Distance is far less important than direction to the navigator. If the navigator is going the right way, he will eventually reach his destination.

Annual migrations of land birds told the south sea islanders the maximum distance of the next life-supporting land. As they approached landfall, the presence of sea gulls told them they were within 25 miles, for gulls never venture farther from shore.

The modern navigator, with a greater need to know the distance from destination, had to wait for the direction-finding function of low frequency radio to get the first electronic measure of this important factor. He computed it in two stages. First, he turned to put the bearing pointer on the wing, noting the time between bearings and the number of degrees of bearing change. From this, he computed the time to the station. Second, he multiplied the time to the station by the velocity to estimate the distance he so much desired. (Time to station is, of course, more important than distance.)

Refinements came swiftly, though their implementation in the field was slower. Automatic electronic timing gave a precise measure of slant range. Ground radars could give aircraft

a measure of distance from the station or location over the ground. DME, which incorporates the use of an airborne receiver, gives the navigator a precise measure of the distance to the location of the transmitter on the ground. DME is of more navigational value than ground radar due to its continous access and the fact that the DME ground stations are plotted on charts but the GCI/ASR sites are not.

Time was more important to those who dwelt around the Mediterranean than to the Polynesians. Commerce was as much a function of time as of cargo space. Time was money. By 600 BC, the Phoenicians were estimating their speed over the water by dropping a stick into the sea and timing (with an hourglass) how long it took to go the length of the ship. By Jesus' time, the Romans were estimating speed overwater by counting the revolutions of a free-moving water wheel attached to the side of the vessel. Then 1,600 years later, navigators were tying knots in a line every 15 feet, attaching the line to a log, throwing the log aft and counting the ships speed in "knots" as the vessel pulled away over a specified period of time.

These velocity estimates of a ship over the waters were precursors of the airspeed indicator. The airspeed indicator measures the difference in total and static pressure. The difference, dynamic pressure, indicates the velocity of an aircraft through the air, measured in "knots."

CONCLUSION

Throughout history navigators have safely found their way. They have given today's navigator a long and illustrious heritage.

Modern aerial navigators, like those who went before, must have the cool, inquiring mind of the scientist. They must possess the knowledge of the elements that comprise their vocation and understand their relationships. They must be able to apply the navigation elements in unusual situations, analyzing the collected clues and synthesizing them into an estimate of the safe radial to follow or an estimate of intermediate position.

In addition, they must possess the sensitivity of the artist. Seldom will they have all the desired information with the artist's intuition. They must supply the missing parts. Navigators, since the dawn of recorded time, have successfully done this.

Dr Blevins completed Aviation Cadet Navigator Training in 1959. Following EWO training, he was assigned to Hill AFB. In 1963, he completed pilot training and then served at MacDill AFB and in Okinawa. He was classified among the top 5 % of all Air Force fighter pilots at the time of his retirement for disability in 1966. Dr Blevins now is Associate Professor of Finance, University of Montevallo.

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